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*Printed by Josiah Fletcher, Norwich.*

AN

# ACCOUNT

OF

# Animal Secretion,

## The Quantity of Blood

In the Humane Body,

And

## Muſcular Motion.

By *James Keill*, M. D.

*Profecto veriſimile eſt, &* Hippocratem *&* Eraſiſtratum, *& quicunque alii, non contenti Febres & Ulcera agitare, rerum quoque naturam ex aliqua parte ſcrutati ſint, non ideo quidem Medicos fuiſſe, verum ideo quoque majores Medicos exſtitiſſe.* Celſ. *in* Præf.

*LONDON*,
Printed for GEORGE STRAHAN at the *Golden Ball* againſt the *Royal Exchange*.
1708.

# THE PREFACE.

*Diseases being purely Disorders of the Animal Oeconomy, whatsoever can add any new Light to our Knowledge of this, must necessarily clear the Nature of those, establish the Practice of Physick upon a surer Foundation, and enable Physicians to make truer and more certain Judgments in most Cases.*

*The Animal Body is now known to be a pure Machine, and many of its Actions and Motions are demonstrated to be the necessary Consequences of its Structure. The Manner of Vision is shown in Opticks.* Borelli *has given us the Mechanism of the Bones and Muscles for the moving of*

*the Joints. And since the Discovery of the Circulation of the Blood by the famous Dr.* Harvey, *many useful Propositions concerning its Motion and Velocity have been determined by* Bellini. *Dr.* Pitcairne *has explained the mechanical Structure of the Lungs, shewn us the reason of the different Passages of the Blood; thro' the Heart of the Fœtus, the necessity of breathing after Birth, and how the ante-natalitial Ducts are stopp'd by breathing: He has likewise demonstratively explain'd the Symptomes of the Diseases of the Eyes, and demonstrated the circular Figure of the Orifices of the Glands. Dr.* Freind *has wrote in a mechanical way upon the Menses; Dr.* Cheyne *upon Fevers; and Dr.* Mead *of Poisons, and all of them have handled these Subjects more rationally than ever any did before them. In the follow-*

*following Sheets is contained a Calculation of the Force of the Air upon the Blood in Breathing, of the Quantity of Blood in the Human Body, of its abſolute Velocity in the* Aorta. *The uſe of the Spleen and* Vena Porta *is now no longer a Myſtery; and many* Phœnomena *of the Animal Body which the Ages paſt thought inexplicable, have now by ſeveral been made the Subjects of Geometrical Demonſtration. That many Things ſtill remain undiſcovered, is not, that of their own Nature they are leſs capable of Demonſtration; but that the* Data *are not ſufficient, we are not yet fully appriſed of all the Circumſtances, which conduce to produce ſuch* Phœnomena. *If ſome things which to former Ages have appeared unaccountable, are now as clear and demonſtrable as the Preſſure of the Air, why ſhould we not hope for a Diſcovery*

*of the Things that are ſtill hid from us? If we endeavour after them, there is all the reaſon in the World to believe we ſhall have Succeſs, if we conſider the Progreſs that has already been made, notwithſtanding the mechanical Philoſophy as applied to Phyſick is ſtill in its Infancy.*

*Now ſince the Animal Body is a pure Machine, and all its Actions from which Life and Health do flow are the neceſſary Conſequences of its Oeconomy; muſt not all the Symptomes of Diſeaſes be likewiſe the neceſſary Conſequences of the Alteration of this Oeconomy? And doe they not as neceſſarily flow from this Change, as the Actions by which Life and Health are continued did flow from the Oeconomy before the Change. If a Pendulum of ſuch a length makes a Clock to goe exactly true; does not the Alteration of the Pendulum as neceſſarily cauſe*

*cauſe it to go too faſt or too ſlow; and when all the reſt of the Movement is known to be in good order, does not the quick or ſlow Motion of the Clock, as neceſſarily ſhow the Fault of the Pendulum? It is the ſame thing in the Animal Body, for the ſame reaſoning holds good in all ſort of Machines, whoſe Motions are the neceſſary Conſequences of their Structures: nor is the Caſe in the leaſt altered, that we have a Principle within us, not ſubject to the Laws of Motion; for our Souls are not at all conſcious of the inward Motions of the Body upon which Life and Health depend, and tho' it do's ſometimes influence our Health, yet the Irregularities it produces in the Oeconomy are to be rectified the ſame way as if they had proceeded from other Cauſes. Therefore it demonſtratively follows that the greater our Knowledge of the Animal*

*Oeconomy is, the better the Nature of Diſeaſes muſt be known.*

*It muſt indeed be confeſſed that this Method of improving the Art of Phyſick is full of Difficulty, but the Nature of things cannot be altered; if it is to be improved, it muſt be by a Knowledge in the Animal Oeconomy, there being no other Method but what does really and in effect depend upon that.*

*Some do pretend that the Art of curing Diſeaſes, is only to be promoted by Experiments, by obſerving what Things are hurtful, what beneficial in Diſeaſes, that the Study of Nature and the Knowledge of the Body is altogether ſuperfluous, and of as little uſe, as it would be to a Sailor to know the Reaſon of the Tides, or how to explain the Phœnomena of the Loadſtone. But if we conſider the Number of Diſeaſes, their different*

*rent Species, different Appearances according to the almoſt infinite Variety of Conſtitutions of our Bodies, and the Air in which we live. If we reflect likewiſe on their various Complications, on the infinite Variety of Medicines, and the critical Times of uſing ſometimes one and ſometimes another, we may as well expect that a blind Man ſhould ſhoot flying, or one that is deaf tune an Organ, as that any one without the Knowledge of the Animal Oeconomy ſhould ever find out a Remedy for any one Diſtemper. The Art of curing did indeed at firſt riſe from Experiments, and it cannot be denyed that ſeveral good Remedies have been found out by chance, or rather by Divine appointment, as without doubt the Uſe of the Bark was by the Indians; whom we may reaſonably ſuppoſe to have been ignorant of the Animal Oeconomy, but*

*no Man can think this a good Method for improving of any Science: If indeed Experiments are directed, by a Knowledge in the Animal Oeconomy, ſomething may be hoped for from ſuch a Method, and the greater the Skill is by which the Experiments are directed, the greater will be the Probability of Succeſs; becauſe by that we can aim more directly and certainly at the Irregularities of the Oeconomy, and he that knows the Diſeaſe is more likely to cure than he that is wandring and dubious in his Mind, and uncertain what it is he ought to aim at. If he hits the Mark it is owing more to mere chance, than any good Skill. Experiments are the only Foundation upon which by a juſt reaſoning we come at the Knowledge of any Phœnomenon of Nature. Thus only Anatomical Experiments, and Obſervations*

*ons upon the Structure of the Parts, Nature of the Blood, and Secretions, can enable us to understand the Phænomena of the Animal Body; without them the raising of Theories and Hypotheses is but building of Castles in the Air. The Theory indeed of any Art, which has already arrived at its highest Perfection, and which has all its Circumstances known, may perhaps be of as little use, as that of the Tides and Loadstone would be for sailing in the Channel: But either of these might be of great use to a Sailor taken out of his Knowledge to an unknown Part of the World. Physick has not as yet arrived at its greatest Perfection in the curing of any one Disease, we are still ignorant of more than we know, and the Circumstances of Diseases are infinitely various, and no general Rules whatsoever can be applied to*

*particular Caſes, without the Knowledge of the reaſon of the Rule, that is, without underſtanding the Animal Oeconomy, upon which all Rules of Phyſick are built.*

*But the Method of curing Diſeaſes, by drawing Indications from the evident and conjunct Cauſes, has been always moſt approved by the beſt and Generality of Phyſicians. The Knowledge of theſe Cauſes is not to be attained by reaſon, but by a cloſe and aſſiduous Obſervation of all the Appearances in the ſeveral Stages of a Diſtemper. The firſt that excelled in this Knowledge was the Divine* Hippocrates, *whoſe Delineations of Diſeaſes are truly charming. In them one may diſcern a wonderful Attention to all even the minuteſt Operations of Nature, which produced a ſurprizing Sagacity in judging of future Events. In this Method ſeveral*

*ral of the Ancients have followed him, but none ever came ſo near to him, as the deſervedly renowned Dr.* Sydenham, *and Dr.* Morton, *whoſe Hiſtories of Diſeaſes, for a full, exact and nice Enumeration, and Deſcription of evident Cauſes, Signs and Symptomes, for a judicious diſtinguiſhing of the ſeveral Species of the ſame Diſeaſes, and for juſt Prognoſticks founded upon a careful Obſervation of the common Effects of ſuch and ſuch Apearances, have ſurpaſſed all Hiſtories of the Modern Phyſicians.*

*This is the Knowledge which added to that of the Animal Oeconomy can only make a Phyſician, one skilled in Geometry may as well pretend to be a good Aſtronomer, without knowing the Motions and Revolutions of the Heavenly Bodies, as a Philoſopher, or one skilled in the Animal Oeconomy,*

*to*

*to be a Physician without the exact Knowledge of the Histories of Diseases. And as one ignorant of Geometry can make but a wretched Astronomer, so he can make no better a Physician that has not laid a good Foundation of the Animal Oeconomy. If we consider the Animal Body as a Machine, its Diseases, and all their Symptomes are only the irregular Motions of the Machine. Now suppose a Man ignorant of the Structure of a Clock or Watch, it is impossible he should ever be able to put it in right Order, tho' he had never so exact an History of its irregular Motions. So a Physician ignorant of the Animal Oeconomy, is ignorant of the Structure of the Machine he undertakes to regulate, and the best and exactest Histories of Diseases can never suggest to him any Indication of Cure. It is therefore the Ani-*

*mal Oeconomy which alone can enable us by reaſoning upon the Cauſes, Signs and Symptomes of Diſeaſes, to find out their Natures, and to deduce true and juſt Indications of Cure.*

*If we examine the Method of curing any Diſtemper we ſhall find what I have ſaid to be true. For Inſtance, do not all the Symptomes of the Jaundice ſhow us that the Liver is obſtructed? And do we not deduce this Obſtruction by our Knowledge of the Animal Oeconomy? And does not this Obſtruction indicate, Bleeding, Vomiting, Purging and Deobſtruent Medicines, which are uſed in curing of this Diſeaſe? If we know the Nature of the Humour which cauſes the Obſtruction, perhaps Remedies might be found to cure ſuch Jaundice as are now found to be incurable: For different Subſtances require different Reſolvents, as every one*

*that*

*that is acquainted in Pharmacy and Chymiſtry knows. From the Symptomes of the Jaundice we juſtly draw the Indication for giving deobſtruent Medicines, but what are the moſt proper Medicines of this kind, we know not; becauſe we are ignorant of the Nature of the Obſtruction. Our Indications therefore are true and juſt, ſo far as our Knowledge of the Animal Oeconomy reaches; but where that leaves us we only grope in the dark, and find out Remedies by Chance.*

*But this will be ſtill more evident if we conſider, there is no Diſeaſe, better known, or which has its moſt minute Circumſtances better deſcribed than a Tertian Fever; yet becauſe we are ignorant of the Nature of the Blood, which is this Seat of the Diſeaſe, its Hiſtory does not help us to any Indication, which if anſwered will*

*will work a Cure, but we are obliged to the ignorant Indians for our knowledge in curing this Diſeaſe. And here again to ſhew the Neceſſity of the Knowledge of the Animal Oeconomy, and how vain a thing Empiriciſm is, tho' a more noble Specifick than the Bark was never known, yet we are frequently forc'd, when Intermitting Fevers are complicated to call in to our Aſſiſtance the Knowledge of the Animal Oeconomy, and by Vomiting, Purging and other proper means, to render that Specifick uſeful which before was of no effect.*

*If the Animal Oeconomy were perfectly underſtood, and the Hiſtories of Diſeaſes exactly known, the right Method of curing each Diſeaſe might be evidently and certainly deduced; and therefore when the Hiſtory of a Diſeaſe is exactly known, if the right Method of curing it cannot be deduced, it muſt be becauſe the Animal*

*Oeconomy is not understood; and from hence it follows that our Skill in curing of Diseases whose Histories are exactly known, (abstracting what we are obliged to Empiricks for) is always proportional to our Knowledge of the Animal Oeconomy.*

*The Animal Oeconomy is its self a considerable Part of natural Philosophy, and our Bodies are strongly influenced by Variety of Diets, and so many things from without, that indeed the whole study of Nature seems to be useful to him that would understand it. And every discovery in things that affect us, seems to be an Improvement of Physick. Some of the Ancients have indeed left us very judicious and accurate Histories of Diseases, but since the discovery of the Circulation of the Blood, and the late Improvement of natural Philosophy, our Reasonings upon these Histories, in order to find out the Seat and Nature*

*of*

*of the Diſtemper and from them to deduce a right Method of curing, and the whole Practice of Phyſick by the Invention of many uſeful Remedies, is ſo much refined, that who ever ſhould affirm the contrary, would ſeem to me neither to have read the Ancients nor to be acquainted with the Practice of the Moderns.*

*But notwithſtanding the great Advantages Phyſick has received from natural Philoſophy, it muſt be owned, that it has likewiſe received a very great detriment from the too common Method of philoſophizing; that is by laying down of Principles not drawn from the* Phœnomena *of Nature, but uncertain Fictions of the Brain; ſuch as are the firſt and ſecond Elements of the* Carteſians, *which are purely Chymerical, and have no Foundation in Nature; and yet their whole natural Philoſophy depends upon them: Tho' their reaſoning upon ſuch fictitious*

*tions Principles were juſt, yet no* Phœnomenon *of Nature demonſtrating their Exiſtence, the beſt that cou'd be ſaid of their Philoſophy is, that for ought we know, it is meerly poſſible; but that Nature does actually work this way, can never be ſhown, till the truth of their Principles can be demonſtrated. Moſt Theories of Diſeaſes are built upon ſuch Principles, and therefore we never can have any Certainty, or indeed ſo much as a Degree of Probability, that the Indications drawn from them are right, or ſuch as if anſwered, would cure the Diſeaſe. If a Man may ſuppoſe any Principles which are not evidently falſe, he may at the too common looſe way of reaſoning, give a thouſand Solutions of the Nature of every Diſtemper, all equally true, and all indicating different Methods of curing. Tho' ſuch a Knowledge may ſatisfie the Curioſity*

*Curiosity of a Philosopher, yet it can be no sufficient ground for establishing the Practice of Physick upon. For a Man to hazard his Life (and he ought to be more cautious of another's) upon the truth of an Hypothesis which is barely possible, is to run a greater Risque than he does, who ventures his Estate in a Lottery, where it is only possible, but not at all probable that he should be a Saver.*

*But this sort of Philosophy is not only useless, but it is also prejudicial to Physick; for Men being generally fond of the Productions of their own Brains have studied these more than they have done the Operations of Nature in the several periods of Diseases, and have not stuck to mould and frame Diseases to answer their Hypotheses; so that most of the late Histories of Diseases, are only Philosophical Romances, and contain no-*

*thing of that diligent Obſervation of Nature which gained* Hippocrates *immortal Honour, and without which it is impoſſible that ever the Art of Phyſick ſhould be improved.*

*But ſuch is the Narrowneſs of the Humane Intellect, that few Men are fitted for various Studies, or even for the ſeveral Parts of the ſame Science. Many have been very nice and exact in making Aſtronomical Obſervations, that have had but a very moderate Skill in Geometry, and ſuch as have excelled in this have been deficient in that. And Men either from a want of Integrity and a Senſe of that Truth and Juſtice that is due to Mankind, or from a natural Fondneſs of their own Qualifications, and an Unwillingneſs to think any thing of which they are ignorant, neceſſary to the Science they profeſs, have generally recommended and extolled thoſe Parts which they beſt*

*beſt underſtood themſelves, but bantered and decryed thoſe they were leſs skilled in, tho' not leſs neceſſary and uſeful. Natural Phyloſophy and the Hiſtories of Diſeaſes muſt go hand in hand in the improving the Art of curing; it is not poſſible to make any uſe of the laſt without the Knowledge of the firſt. And I may venture to ſay, that there is no Man that practiſes, but who does it upon ſome Knowledge of the Animal Oeconomy, or ſome notions of his own which are more or leſs clear according to his Skill in natural Philoſophy. And for the Truth of this, I appeal to Dr.* Sydenham's *own Writings, who by his philoſophyzing has evidently ſhewn us the Neceſſity of that Science, he ſo much decryed, and ſo little underſtood. He was undoubtedly a great Man, and the World will always be obliged to him for his accurate Hiſtories of Diſeaſes, but*

*there is no Man without Errors, and where one of his deſerved Character falls into a Miſtake, it does a great deal more hurt, than if hundreds of others of leſſer Note had been guilty of the ſame.*

*The following Treatiſes contain a few Thoughts about ſome of the principal Parts of the Animal Oeconomy; It was the Conſideration of the Uſe of the* Vena Porta *which gave me the firſt hint to think that the ſeveral Humours of the Body were formed by the Attraction of the Particles of the Blood; which when I had communicated to my Brother, he was pleaſed to ſee his Theorems of Attraction illuſtrated by ſo eminent an Inſtance, and ſent me the Demonſtration of the third Propoſition.*

*The firſt that I know of who, to explain Secretion, thought it neceſſary to conſider the ſtate of the Blood at different diſtances from the Heart, was the*

*the ingenious Dr.* Cockburn; *and 'tho he was not then aware of this Principle of Attraction; yet he wisely foresaw that different Velocities of the Blood were requisite for secerning of different Fluids.*

*As the Learned Dr.* Gregory *has, shewn us, in the Preface to his Astronomy, that the Gravitation of the Heavenly Bodies towards one another was known to the Ancient Philosophers; so this Power by which the smal Particles of Matter attract one another was the Doctrine of* Hippocrates, *(a) whose whole Philosophy is built upon a certain* Propension *which some things have to one another, whereby they* attract, retain *and* alter *one another.* Galen *(b) does assert this Attraction to be*

(a) Vide Mr. *Le Clerc*'s Histoire de la Medicine.

(b) Præterea conspirabile & confluxile totum corpus esse, Naturamque omnia juste & artificiose peragere, facultatibus scilicet præditam, quibus singulæ particulæ convenientem sibi succum ad

*be an univerſal Power in Matter and* (c) *compares it to the Power by which a Loadſtone draws Iron.* (d) Hippocrates *explains the manner that purgative Medicines operate juſt as we have done. And* Galen *in his Treatiſe* de Purgantium Medicamentorum Facultate, *does bitterly inveigh againſt all thoſe who in oppoſition to* Hippocrates *did aſſert that all purges, purged all Humours indifferently; and concludes that every purgative Medicine draws to its ſelf its proper*

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ad ſe trahunt, attractum vero coaleſcere, accreſcereque omnibus ſuis partibus faciant, *cap.* 12. *lib.* 1. dé Natural. Facultat. Oſtenſum eſt a nobis in Commentariis de Potentiis Naturalibus, Naturam uniuſcujuſque particulæ, quatuor uti potentiis; attractiva proprii alimenti, & ejuſdem retentiva. *Comment.* 1. *Aphor.* 22.

(c) Ergo ad quem modum trahatur in commune inveſtigemus; quo porro alio, quam ſicut a magnete lapide ferrum, qui ſcilicet talis qualitatis trahendæ vim habet. *Lib.* 2 *Cap.* 7. de Natural. Facultat.

(d) Τὸ γὰρ φάρμακον ὁκόταν ἐσχυθῇ ἐς τὸ σῶμα, πρῶτον μὲν ἕλκει, ὃ ἂν αὐτέῳ κατὰ φύσιν μάλιστα ᾖ τὸ ἐν τῷ σώματι ἐνεόντων. ἔπειτα δὲ καὶ ταλλὰ ἕλκει τὸ καθαίρει.

*Humour*

*Humour. And he ſtrenuouſly maintains a* Vis Attractrix *in Nature againſt* Epicurus, Aſclepiades, Eraſiſtratus, *and others in his Book* De Naturalibus Falcultatibus. *All which does ſufficiently ſhow that this Attraction of the ſmall Particles of Matter is no Innovation in Philoſophy.*

*The maner by which I do ſuppoſe the Glands do ſeperate the ſeveral Humours from the Blood, is much the ſame with that of Dr.* Morland's *publiſhed in the Philoſophical Tranſactions. What I have ſaid concerning the Quantity of Blood is ſufficient to ſhow how little reaſon common Opinions are ſometimes grounded upon. And the Difficulty of the Subject, and the new Method of handling it, will I hope procure this ſhort Eſſay a favourable Reception. The Theory of Muſcular Motion does follow ſo naturally and eaſily from the Principle of Attraction, that one would be al-*

*moſt*

*most tempted to believe it the genuine Method of Nature. The Determination of the* Vis Elastica *was the Thought of the Learned* John Bernouli; *but this way of demonstrating it was communicated to me by my Brother: I am too sensible of my own Inabilities to persue those Thoughts which I have only started, and I should be pleased if they were of any use to Men better qualified to make Discoveries in Nature.*

*Tho' any one with a moderate Skill in the Mathematicks may understand these Discourses, yet without that no one can judge of their Truth, and Usefulness in explaining the Animal Oeconomy.*

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## ERRATA.

PAge 10. line 20. read *distance.* p. 14. l. 11. r. *describe the Hyperbola b s a.* p. 17. l. 2 for *or* r. *for*; l. 11 dele is *attracted.* p. 26. l. 20. and 21. r. $p : x :: t^2 : T^2 + o^2 : O^2$, that is $p : x :: t^2 + o^2 : T^2 + O^2$ and therefore $\dot{+} = \frac{p \dot{+} T^2 \dot{+} O^2}{2 \dot{+} o^2}$ p. 40. l. 2. r. *Branches.* p. 65. l. 18. r. *Sudorificks.* p. 145. l. 9. for a *hundred* r. a *thousand.* p. 176. l. 8. for *Secretion* r. *Section.*

# OF

# *Animal Secretion.*

IN explaining the manner, how the ſeveral Fluids of the Animal Body are ſeparated from the Blood, I ſhall ſhew,

Firſt, *How they are formed in the Blood, before they come to the place appointed for Secretion.* And,

Secondly, *I ſhall demonſtrate in what manner they are ſeparated from the Blood by the Glands.*

*The Blood conſiſts of attracting Particles.*

The Blood of all Animals, when drawn out of the Body, does naturally, and of itſelf, divide into two different parts: Of which the Red does in a little time coagulate, but

the Serum remains fluid. If we view a drop of Blood with a Microſcope, we diſcern a number of Red Globules ſwimming in a limpid Fluid; and perceive how the Globules, attracting one another, unite like Spheres of Quickſilver, which, as they touch, run into one another: And conſequently the Blood divides into two parts.

*The Serum conſiſts of attracting Particles.*

After the Coagulation of the Red Globules of the Blood, if we examine the Serum with a Microſcope, we find in it likewiſe a great number of Corpuſcles of various Figures and Magnitudes, ſwimming in a limpid Fluid. Theſe do not attract and unite with one another as the former did, till ſome part of the Fluid, in which they ſwim, has been evaporated by Heat; and then they likewiſe attract one another, and form a Coagulum, as the Globules did.

This

This therefore is matter of fact, that the Blood consists of a simple and limpid Fluid, in which swim Corpuscles of various Figures and Magnitudes, and endued with different Degrees of an attractive force. Now of such Particles, as the Blood consists of, must the Fluids be composed, which are drawn from it; and as in the Blood the Particles attract one another, and cohere together, so likewise may the Particles of the Fluids, which are separated from it.

*Most Fluids consist of attracting Particles.*

Most of the Liquors we know are form'd by the Cohesion of particles of different Figures, Magnitudes, Gravities, and attractive Powers, swimming in an aqueous Fluid, which seems to be the common Basis of all. Why are there so many sorts of Water, differing from one another in Properties? Is it not, because of the Corpuscles of Salts and Minerals

with which the Element is impregnated? What elſe is Wine, but Water impregnated with the Particles of the Grape, and Ale with Particles of Barley? Are not all Spirits the ſame Fluid ſaturated with ſaline or ſulphureous Particles? And all Liquors are more or leſs fluid, according to the greater or ſmaller Coheſion of the Particles, which ſwim in this Aqueous Fluid; and there is hardly any Fluid without this coheſion of Particles, as is apparent by the Bubbles which ſtand upon the Surface of Water, Wine, and even of ſome Spirits.

*The Secretions conſiſt of attracting Particles.*

But that ſome of the Fluids, which are ſecerned by the Glands from the Blood, are actually compoſed by the Coheſion of ſeveral ſorts of Particles, is very evident. We know that in Milk there are three or four ſeveral ſorts of Subſtances, and yet when

when it is examined by the Microſcope it appears, like Blood, to conſiſt of very ſmall Globules, ſwimming in a limpid Fluid. Urine has the ſame Appearance, and contains perhaps more Principles: And there is no doubt but that Tears, Spittle, and Sweat are all compounded Liquors. If ſome of the Fluids which are ſecreted by the Glands are not eaſily reſolved into their compounding Parts, we can no more conclude from thence, that they are not compounded, than we can that the Blood is not, becauſe it does not ſeparate into about thirty different Fluids of which it is compoſed, and which are conſtantly extracted from it by the Glands.

*The Reaſon why it is not evident in all.*

If the Particles, which attract one another, are ſtill more powerfully attracted by the Particles of the Fluid in which they ſwim, than by

one another, they can never of themſelves ſeparate from the Fluid; and this is the caſe of all Salts diſſolv'd in a large quantity of Water and of Urine, when it neither breaks nor ſettles. But if the Particles, which ſwim in the Fluid, are more ſtrongly attracted by one another, than they are by the Fluid in which they ſwim, then this Fluid muſt neceſſarily go into parts; and the Corpuſcles uniting, will either ſink, ſwim, or aſcend in the Fluid, according to their ſpecifick Gravities, unleſs there ſhould be ſo many interſtices within the coagulated Maſs, as will receive the greateſt part of the Fluid. From hence it is plain that the red part of the Blood conſiſts of Particles which attract one another, more than they do the watry Fluid, in which they ſwim; and that the other Particles

ticles, which are in the watry Fluid of the Serum, are more attracted by it than by one another. But if part of this watry Fluid be evaporated, by this means, the Particles attracting approaching nearer, the Force of their Attraction is increased, and then they unite; and consequently this force must be much stronger in Particles that are very nigh one another, than when they are at a distance.

*This Attraction is an universal Power in Matter.*

This Power, by which the Particles of the Blood attract one another, is the same with that which is the Cause of the Cohesion of the Parts of Matter: And was first communicated to me by my Brother at *Oxford*, above seven Years ago; who had no sooner discovered it, but he deduced from it the Cohesion of the parts of Matter, the Cause of the Elasticity of Bodies, of Fermenta-

mentations, Diſſolutions, Coagulations, and many other of the Operations in Chymiſtry. And ſince it will appear, that the whole Animal Oeconomy does likewiſe depend upon this attractive Power; it ſeems to be the only Principle, from which there can be a ſatisfactory Solution given of the *Phænomena*, produc'd by the *Minima Naturæ*; as that other attractive Principle, which is of a different kind from this, and was firſt diſcovered by the incomparable Sir *Iſaac Newton*, demonſtratively explains the Motions of the great Bodies of the Univerſe: Which is not in the leaſt diſturb'd by the attracting Power we now ſpeak of, which only exerts its ſelf in Particles that are at a ſmall diſtance from one another. Now, that there is ſuch an attractive Power in Nature as this we have mentioned, I think,

can be denied by none, that duly conſider the Experiments and Reaſons given for it, by Sir *Iſaac Newton*, in the Queſtions annexed to the Latin Edition of his Opticks.

From this Principle that the Blood conſiſts of Corpuſcles of various Figures and Magnitudes, and endued with various Degrees of an attractive Power, and that of ſuch Particles the Fluids ſecerned by the Glands are compoſed; I ſay, from this Principle (for which we have ocular Demonſtration) I ſhall endeavour to ſhew how the Corpuſcles that compoſe the Secretions are formed in the Blood, before they arrive at their ſecerning Glands: having firſt laid down the following Propoſitions, being only ſo many of the Laws of Attraction as at preſent we have occaſion for, the reſt being

being contained in my Brother's Theorems, publiſhed in the *Philoſophical Tranſactions.*

*Some Laws of Attraction in ſmall Particles of Matter.*

**Prop. I.** *There is a Power in Nature by which each Particle of Matter attracts every other Particle, with a Force that increaſeth in a greater Proportion than that, by which the Squares of the diſtance decreaſe,* viz. *in a reciprocal triplicate, or quadruplicate Proportion to the diſtances.*

For were the Particles, that compoſe the attracting Body, endued with a Power that attracted only with a Force reciprocal to the Squares of the Diſtances, the Attraction would not be much ſtronger at the Contact, than at ſome determined Diſtances from it: As is evident in the Caſe of Gravity, which ariſes from a Power of attracting reciprocally as the Squares of the Diſtances;

ces; Bodies being of the ſame Weight, when they touch the Earth, as they are at an hundred Feet diſtance. But by all Experiments, this Power is much greater at the Contact, or Extremely near it, than at any determined diſtance. The Particles of Salt diſſolved in a large quantity of Water, do not ſenſibly attract one another, till part of the Water has been evaporated; by which means approaching each other, their attractive Force increaſes, they run to one another, and uniting form Cryſtalls, whoſe Parts have a ſtrong Coheſion. And therefore the Force, by which each Particle attracts every other Particle, muſt encreaſe in a much greater Proportion, than that by which the Squares of the diſtances decreaſe.

Prop.

Prop. II. *The attractive Force is* cæteris paribus *proportional to the Solidity of the Particles.*

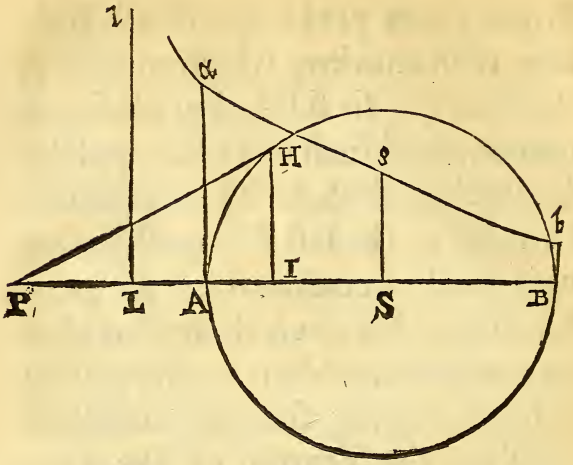
The attractive force of a Particle is compoſed of the Sum of all the Attractions of the Parts of that Particle: Now theſe Parts are moſt numerous in the moſt ſolid Particles, and therefore *cæteris paribus*, their attractive Force is ſtrongeſt.

*Schol.* This Propoſition is to be underſtood of the ſmalleſt Particles of Matter, and not of the Corpuſcles made up of thoſe Particles. For Corpuſcles may be ſo compounded, that the moſt ſolid and compact Particles may make up the lighteſt Corpuſcle, if the Interſtices between the Particles be large, ſo that few of them may be diffuſed thro' a great Space: Such a Corpuſcle, tho' it conſiſts of Particles that are endued with a ſtrong attractive Power,

Power, may yet be ſpecifically lighther than another, which conſiſts of Particles not ſo ſolid, but cloſer together. And ſuch ſort of Corpuſcles I conceive all Salts to be, whoſe Particles of the laſt Compoſition are very ſolid, but that there are great Interſtices between thoſe Particles, into which the Water ruſhing with a force, being ſtrongly attracted, diſſolves the Texture of the Corpuſcles.

Prop. III. *If Particles of Matter attract each other with a Force, that is in a reciprocal triplicate, or a greater Proportion of their diſtances, the Force by which a Corpuſcle is drawn to a Body, made up of ſuch attractive Particles, is infinitely greater at the Contact, or Extremely near it, than at any determined diſtance from it.*

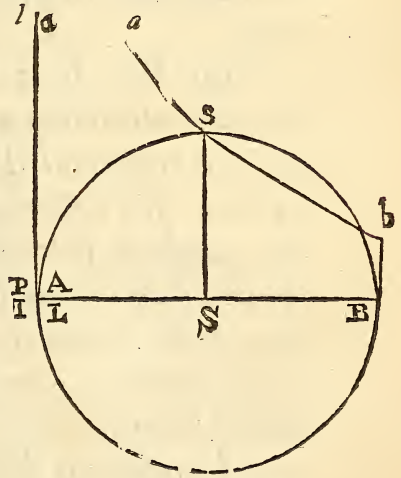
Suppoſe




Suppoſe the Sphere A H B compoſed of Particles, that attract a Corpuſcle P with a Force reciprocally proportional to the Cubes of their Diſtances. Draw the Tangent P H, and from H let fall the perpendicular H I, biſect P I in L, and raiſe the Perpendiculars L l, A a, *S s*, B b, and make S s = to S I: with the Aſymptots L B, L l thro' s, deſcribe the Hyperbola b B a, and the Area a A B b — the rectangle

angle 2 A S x S I will represent the Attraction of the Corpuscle P by the 81 Prop. of Sir *Isaac Newton*'s Principles.

But when the Corpuscle P comes to the Sphere, and touches in A, then the Points P, L, A, I, and H, coincide, and A a becomes the Asymptot of the Hyperbola, and the Area a A B b a becomes infinite, and the rectangle 2 A S x S I being finite, the Area a A B b a — 2 A S x S I will be infinite; and consequently the Force, by which the Corpuscle P is attracted by the Sphere, will be likewise Infinite.




If

If the Sphere consists of Particles that attract in a reciprocal quadruplicate Proportion of their distances, the Force, by which a Corpuscle will be drawn to the Sphere, will be as $\frac{1}{PS^3 \times PI}$. Now when the Corpuscle comes to touch the Sphere, PI becomes = o, and consequently whatever is divided by it, becomes infinite, and therefore the attractive Force of the Sphere at the Contact, being proportional to $\frac{1}{PS^2 \times PI}$, will be infinite.

Prop. IV. *If a Body consists of Particles attracting with a Force that is in a reciprocal Proportion to the Cubes of the distances, or in a greater; and if this Force is not infinitely greater than the Force of Gravity at the Point of Contact, or extremely near it, at any determined distance from the Point of Contact, it must be infinitely less than the Force of Gravity.* This

This is clear by the laſt Propoſition: Or in that Caſe, the Force of Attraction in a Corpuſcle removed from the Contact is infinitely leſs than at the Contact, or extremely near it; but at the Contact it is not infinitely greater than the force of Gravity by Suppoſition: therefore the Force, by which a Particle removed at a determined diſtance from the attracting Body is attracted, is infinitely leſs than the Force of Gravity.

Prop. V. *The force, by which the Particles of Matter attract each other, when extremely near the Contact, is not infinitely greater than the force of Gravity.*

This is evident: becauſe in the ſtrongeſt Coheſion of Particles touching one another, we find that the Weight of ſome Bodies will pull the Particles aſunder, tho' that Body may be prodigiouſly greater and

heavier than the Particles united. Sir *Isaac Newton* calculates from the Inflection of the Rays of Light, that this force near the Contact is 10000 0000 0000 0000 greater than the Force of Gravity.

*Corol.* Particles removed at a determined distance from the Body attracting, are not acted upon by it; because this Force must then vanish, or, which is the same thing, be infinitely less than the Force of Gravity.

Prop. VI. *A large Particle attracts not more strongly than a small one of the same Solidity, but a Diversity of Figures causes different Degrees of Attraction in Particles, that are otherwise the same.*

This attractive Power acts only on such Particles as are extremely near; and therefore of a large Particle, the remotest parts conduce nothing

nothing to Attraction: and for the ſame Reaſon the attractive Force varies, according as the Particles are Cones, Cylinders, Cubes, or Spheres, and *cæteris paribus* a Spherical Particle, has the ſtrongeſt attractive Power

Prop. VII. *If Particles ſwimming in a Fluid, attract one another more ſtrongly, than they do the Particles of the Fluid, the Force, by which they come to each other, will be that by which their attractive Force exceeds the attracting Force of the Fluid.*

For the Particles of the Fluid, that lie directly between the attracting Particles, being more preſſed than the other ambient Particles; they will from the Nature of Fluidity, with that exceſs of Preſſure, drive the other Particles out of their places, and make way for the attracting Particles to come together.

Prop. VIII. *If Particles ſwimming in a Fluid, are more attracted by the Fluid, than by one another, they will recede from one another, with a Force that will be equal to the difference of their mutual Attraction, and the Attraction of the Fluid.*

For the ambient Particles of the Fluid attracting more ſtrongly, will with their exceſs of Force draw the other Particles to themſelves, and make them to recede from one another.

Prop. IX. *The Force, by which Particles attracting one another cohere, is greater* cæteris paribus, *where the Contact is greater.*

For the parts that are farther remov'd from the Contact, conduce nothing to the Force of the Coheſion; and a greater Power muſt be requiſite to ſeparate two Particles, which

which cohere in two points, than two Particles which cohere only in one point, if the Degree of Coheſion be equal in each point. Thus two poliſhed Marble-ſtones (ſuppoſe a Foot ſquare) adhere more ſtrongly than any other two Bodies of a Foot ſquare, which are not ſo ſolid, but have more Pores and Interſtices between their parts, and which will not receive ſo good a poliſh, by which the parts come to a cloſe contact with one another.

Prop. X. *If the attracting Corpuſcles are elaſtick, they muſt neceſſarily produce an inteſtine Motion, greater or leſſer, according to the Degrees of their Elaſticity and attractive Forces.*

For after meeting they will fly from one another with the ſame Degree of Velocity (abating the reſiſtance of the Medium) that they met

together with; but when they approach other Particles in their Resilition, their Velocity must increase, because they are afresh attracted, and therefore meeting a second time, they will recede with a greater Velocity than they did at their first Concursion: and so their Velocities will be increas'd by every Concursion and Resilition, which must necessarily produce a sensible intestine Motion; and the stronger their attractive Force, and the greater their Elasticity, their Concursions and Resilitions will be the more sensible.

Prop. XI. *Particles attracting one another in a Fluid, moving either with a swift or slow progressive Motion, attract one another just the same, as if the Fluid was at rest, if all the Particles move equally; but an unequal Velocity of the Particles does mightily disturb their Attractions.*

The

The Particles do all by Hypotheſis move equally, and conſequently the progreſſive Motion of the Fluid does not alter their diſtances, that is to ſay, it does not repel them from one another; and conſequently they muſt attract one another with the ſame Facility, as if the Fluid was at reſt. But if ſome Particles move faſter than others, ſome muſt change their Poſition in reſpect to each other, and thoſe parts, which by the force of Attraction would have come together, will by this unequal Motion be carried from one another. Thus Salts do not cryſtallize, nor the terreſtrial Particles of Urine attract one another, and unite, till the Water, in which they are diſſolved, is almoſt cold; and the inteſtine Motion of its Particles, cauſed by heat, is quieted.

Theſe are the Laws, by which Secretions are firſt formed in the Blood, before they are ſeparated by the Glands. The Particles of the Blood returning by the Veins mutually attract one another, and cohering form Globules too big for any Secretion; and therefore there was an abſolute neceſſity, that they ſhould be broken and divided in the Lungs by the force of Reſpiration: which becauſe it is commonly thought to be inconſiderable, by reaſon we are not ſenſible of it, I ſhall therefore here make an Eſtimate of it.

*The Force of the Air upon the Blood in breathing determined*

It is demonſtrated by the Writers of Hydroſtaticks, that Weights, which force out of the ſame Tube equal Quantities of the ſame Fluid, are to one another as the Squares of the times the Fluid is forced out in. But if the times are equal in which the

the ſame Quantity of the Fluid is forced out thro' unequal Tubes, then the Powers are reciprocally as the Orifices of the Tubes; and therefore Powers which thruſt out the ſame Quantity of a Fluid thro' unequal Tubes, are to one another in a reciprocal Proportion, compounded of the Squares of the Times and Orifices of the Tubes.

Now that I might know by what force the Air is thruſt out of the Lungs in Expiration, I took a thin Hogs-bladder, which I could eaſily blow up with the Breath of one Expiration; and having moiſtened it, that it might neither reſiſt the Air in blowing up, nor the Weights which were laid upon it, I fix'd a ſmall Tube, whoſe Diameter was $\frac{1}{10}$ part of an Inch, to the Neck of the Bladder; then filling the Bladder with Air, I put a Weight of

2 *lib*

2 *lib* 4 Ounces on the top of it: And having repeated the Experiment ſeveral times, I found that this Weight ſqueez'd all the Air out of the Bladder thro' the ſmall Tube in the ſpace of 25 Vibrations of a Pendulum, which vibrated Seconds of a Minute.

Let P ſtand for 2 *lib* 4 Ounces, or 36 Ounces, O for the Diameter of the Tube, T for the time of 25 Seconds, and ſuppoſe ɔc to be the Power, by which the Air is thruſt out of the Lungs in Expiration, o the Diameter of the Aperture of the *Larynx* (which I ſhall ſuppoſe to be $\frac{3}{10}$ parts of an Inch) let t be the Time ſpent in an ordinary Expiration, which is commonly $1''\frac{1}{4}$ or $1''25$. then $P : ɔc : T^2 : t^2 : T^2 + o^2 : O^2$, that is $P : ɔc : t^2 \times o^2 : T^2 \times O^2$, and therefore $ɔc = \frac{P \times T^2 \times O^2}{t^2 \times o^2}$. $= \frac{36 \times 625 \times .01}{1.5625 \times .09} = \frac{225}{0.140625} = 1600$ Ounces

Ounces, equal to 100 *lib*: which is the force by which the Air is thrust out of the Lungs every Expiration. But being Action and Reaction are equal, the Pressure of the Air upon the Lungs every Expiration is equal to the Pressure of an 100 *lib* Weight. If the Gravity of the Air was always the same, and if the Diameter of the Trachea Arteria, and the time of every Expiration were equal in all, this Weight upon the Lungs would be always the same. But since we find by the Barometer, that there is 3 Inches difference between the greatest and the least Gravity of the Air, which is a $\frac{1}{10}$ part of its greatest Gravity; there must be likewise the difference of ten *lib* Weight in its Pressure upon the Lungs at one time and another: for the Momenta of all Bodies, moved with

*The effects of the different Gravities of the Air considered upon Asthmatick People.*

with the ſame Velocity, are as their Gravities. This is a difference, which ſuch as are Aſthmatick muſt be very ſenſible of, eſpecially if we conſider that they likewiſe breath thicker, that is, every Expiration is performed in leſs time; if in half the time, and the ſame Quantity of Air drawn in, then the Weight of the Air upon the Lungs muſt be 400 *lib*, of which $\frac{1}{10}$ part is 40 *lib*, and conſequently Aſthmatick People upon the Riſe or Fall of the Barometer, feel a difference of the Air almoſt equal to half its Preſſure in ordinary breathing. Again, if the *Trachea Arteria* is ſmall, and its Aperture narrow, the preſſure of the Air increaſes in the ſame Proportion, as if the times of Expiration were ſhorter: and therefore a ſhrill Voice is always reckoned amongſt the prognoſtick Signs of

of a Conſumption, becauſe that proceeds from the narrowneſs of the *Larynx*, or *Trachea Arteria*; and conſequently encreaſes the Preſſure of the Air upon the Lungs, which upon every Epiration beats the Veſſels ſo thin, that at laſt they break, and a Spitting of Blood brings on a Conſumption apace.

I ſuppoſe, no body doubts whether this Preſſure of the Air upon the Lungs in breathing be ſufficient to break the Globules of the Blood, and to diſſolve all the Coheſions they might contract in their Circulation thro' the Arteries and Veins. And when the Blood is thus diſſolved and thrown out by the Heart into the *Aorta*; it is evident that the reunion of the Particles requires more or leſs time, according to their ſeveral attractive Powers, even tho' they all moved with the

*By this Preſſure of the Air, the Coheſions of the Globules of the Blood are diſſolved.*

ſame Velocity, and in the ſame Direction.

*How the Union of the Particles is hindered near the Heart.*

But neither doth this happen, for a Fluid moves thro' a Cylindrical or Conical Veſſel (ſuch as the Arteries are) with a greater Velocity at the *Axis* than at the Sides. And again, the Blood is thruſt into the *Aorta* by the whole Force of the Heart, and Fluids when they are preſſed preſs *undequaque*, by which means the Arteries are dilated, and the Blood moves not only forwards, but likewiſe preſſes perpendicularly on the Sides of the Arteries; and as the Sides of the Arteries (being Elaſtick) return, they preſs the Blood from them every way, which muſt produce an inteſtine Motion, and by the 11th Propoſition hinder the Attraction of the Particles, and by this frequent and ſtrong Colliſion of the Particles

of

of the Blood againſt the Sides of the great Arteries, the Coheſions of the Particles, if any of them happen to unite, will be immediately diſſolved. Again, this inteſtine Motion muſt greatly increaſe upon the account that many of the Particles of the Blood are elaſtick: for by this Reſiſtance of the Sides of the Veſſels, they muſt neceſſarily hit one againſt another, and being elaſtick, reflect from one another, and ſo increaſe the inteſtine Motion of the Blood by the 10th Propoſition. Upon this inteſtine Motion of the Blood depends its Heat, which therefore is every where proportional to the *impetus* of the Particles againſt the Sides of the Veſſels, ſuppoſing the Elaſticity of the Particles every where the ſame. Now the *Impetus* of the Particles againſt the Sides of the Veſſels decreaſes, as

the Sum of the Cavities of the Veſſels increaſes: and conſequently where the Sum of the Cavities of the Veſſels is greateſt, there the inteſtine Motion of the Blood is leaſt, and the attractive Power of the Particles *cæteris paribus* is greateſt.

*The Effects of Steel.* By the by, we may obſerve how that Steel, being an elaſtick Body, heats the Blood more than any other Mineral; and how by its Elaſticity, the Force of its own Particles in removing Obſtructions, as well as thoſe of the Blood, increaſe, and therefore it is a better Deobſtruent, than ſome other Minerals, which have a greater Gravity.

*What Particles unite firſt.* The Particles, which unite firſt after the Blood is thrown out of the Heart into the great Artery, muſt be ſuch as have the ſtrongeſt attractive Force; and ſuch as have the leaſt, unite laſt: and all the intermediate

termediate ones according to their ſeveral Natures. The Particles endued with the ſtrongeſt attractive Powers, are by the 2d and 6th Propoſition, the moſt ſolid ſpherical Corpuſcles, and the Quantity of their Contact being the leaſt by the 9th Propoſition, the Secretion, which they compoſe, muſt be the moſt fluid, and ſuch is the Liquor in the *Pericardium.*

The Salts are Corpuſcles that are ſtrongly attracted, and have a moſt cloſe Union with the Fluid of Water; for tho' the Lungs may divide the Particles of Salt from one another, yet ſtill they firmly adhere to the aqueous Humour in which they ſwim, and therefore they may likewiſe at firſt be drawn off: upon which account the Kidneys have their Situation ſo near to the Heart. And indeed, they could not have *The Reaſon of the Situation of the Kidneys.*

been placed at a greater distance, and have separated such a Quantity of Urine as they now do, not only upon the account of the great Quantities of Blood they receive where they are; but likewise, because if they had a more distant Station, other Particles must have united with the Salts and aqueous Particles (as in their present Station some terrestrial Particles do) and consequently the Urine could not have been distilled such as it is now, or at least but in a small quantity.

*What Particles are longest in uniting.*

The Corpuscles, which are the slowest in uniting, must be such as have the weakest attractive Force, which by the 2d and 6th Proposition, are such as have the least Solidity, and such as have their Surfaces the most extended; and therefore Corpuscles, which have plain Surfaces, are longer in uniting than

than ſpherical Corpuſcles, but when united, they cohere more ſtrongly by 9th Propoſition, and compoſe the moſt viſcid Fluids: and therefore the moſt viſcid Secretions, ſuch as the Mucilage of the Joints, are ſeparated at the greateſt diſtance from the Heart, where the Sum of the Cavities of the Arteries is greateſt, the *Impetus* of the Blood againſt the Sides of the Veſſels (which is always proportional to the Velocity of the Blood) ſmalleſt, and conſequently where the Particles move almoſt with an equal Velocity, and therefore the Attractions of the weakeſt are not diſturbed by the 11th Propoſition.

The Gall which is ſecerned by the Liver, and the Seed by the Teſticles, do ſeem to be two conſiderable Objections againſt what has been ſaid. But I will make it appear that they

are so far from proving any thing against this Doctrine of Secretions, that they are the greatest Arguments that could possibly be urged for the truth of it. Nothing does more evidently demonstrate the Intentions of Nature in her Operations, than the various Methods she is sometimes forced to take to bring the same thing about.

*This Doctrine illustrated by the Separation of the Gall in the Liver.*

This is most eminently remarkable in the Secretion of the Gall: which, being to be mixed with the Chyle as it comes out of the Stomach into the *Duodenum*, could no where be so conveniently secerned from the Blood, as where the Liver is placed. Now had all the Branches of the Celiack Artery carried all the Blood to the Liver, from which the Gall was to be separated, it is evident, considering the nearness of the Liver to the Heart, and the intestine Motion of the

the Blood, that ſo viſcid a Secretion, as the Gall is, could never have been formed in the Blood, and conſequently, could never have been ſecreted by any Gland in that place. In this caſe Nature is forced to alter her conſtant Method of ſending the Blood to all the parts of the Body by the Arteries. Here ſhe forms a Vein (which is no Branch of the *Vena Cava*, as all the others are) and by it ſhe ſends the Blood from the Branches of the Meſenterick and Celiack Arterick (after it has paſſed thro' all the Inteſtines, Stomach, Spleen, Caul, and Pancreas) to the Liver. By this extraordinary Contrivance the Blood is brought a great way about, before it arrives at the Liver; and its Celerity is extremely diminiſhed, that all the Corpuſcles, which are to form the Gall may have ſufficient time to attract

one another, and unite before they come to their ſecerning Veſſel. And thus we have found out the uſe of the *Porta*, which, notwithſtanding it makes ſo conſiderable a Figure in the animal Body, yet perhaps no part was ever leſs minded, or had its uſe leſs underſtood by the Writers upon the animal Oeconomy.

But that this is moſt certainly the uſe of the *Porta* will more evidently appear, if we conſider what Nature ſtill does farther in proſecution of the ſame Deſign.

The Cavities of all the Arteries increaſe as they divide. The Sum of the Branches, which riſe immediately from the *Aorta*, is to the *Aorta* as 102740 is to 100000: but as if this Proportion was too little to effect the deſign of Nature, before the Blood arrives at the Liver, the Branches, which immediately

diately ſpring from the Trunk of the Meſenterick Artery, increaſe in a much greater Propotion. The Figure of this Artery, as it lies in the middle of the Meſentery, is after this manner.

And in that Body, from which I took the following Proportions, I found 21 Branches to ſpring immediately from its Trunk. In ſuch parts of which the Trunk of the Meſenterick Artery is 15129

| | |
|---|---|
| The 1ſt Branch is | 2136 |
| 2 | 1936 |
| 3 | 2136 |
| 4 | 2104 |
| 5 | 4489 |
| 6 | 1936 |

| | |
|---|---|
| 7 | 2601 |
| 8 | 3136 |
| 9 | 1681 |
| 10 | 3025 |
| 11 | 625 |
| 12 | 1369 |
| 13 | 1024 |
| 14 | 1849 |
| 15 | 1936 |
| 16 | 529 |
| 17 | 729 |
| 18 | 1156 |
| 19 | 1024 |
| 20 | 1156 |
| 21 | 841 |
| The Sum of all | 37418 |

By theſe Proportions it appears, that the Sum of the firſt Branch is much more than double to the Trunk of the Meſenterick Artery; and therefore the Velocity of the Blood in them is much leſs, than

half what it is in the Trunk. But becauſe the other Branches do not exceed one another ſo much, I ſhall therefore ſuppoſe that the Branches are only double to their reſpective Trunks, and that there are only ſix Series of Diviſions between the Trunk, and the evaneſcent Artery: whereas moſt of the Branches have ſo many Series, whilſt they run upon the Meſentery, and many more upon the Inteſtines, ſo that what we may have exceeded in reckoning the Branches double to their Trunks, is more than made amends for in ſuppoſing ſo few Diviſions. Now from this eaſie Suppoſition, the Velocity of the Blood in the ſeveral Series will decreaſe in the ſame Proportion as theſe Numbers increaſe 2, 4, 8, 16, 32, 64. And therefore the Velocity of the Blood in the evaneſcent Artery will be

64

64 times leſs than it is in the Trunk of the Meſenterick.

As the Trunk of the Meſenterick Artery bears a leſſer Proportion to its Branches, than the *Aorta* does to its Branches; ſo the Branches of the Meſenterick Artery are likewiſe leſs in Proportion to their conjugate Veins, than the *Aorta* is to the *Vena Cava*. The deſcending Trunk of the *Aorta* below the Emulgents is to the *Vena Cava* at the ſame place, as 324 is to 441. But a branch of the Meſenterick Artery is to its correſponding Branch of the *Porta*, as 9 to 25: and therefore the Blood in the Branches of the *Porta* moves above 177 times ſlower than it does in the Trunk of the Meſenterick Artery, and that only upon the account of the encreaſe of the Diameters of the Veſſels. So neceſſary was it to abate the

the rapid inteſtine Motion of the Blood, which might hinder the coaleſcence of the Particles for the Formation of the Bile. The Blood is indeed no where without an inteſtine Motion; but where the Sum of the Cavities of the Blood Veſſels is greateſt, there the inteſtine Motion being moſt languid, the Particles which hit againſt one another, do not reſile, but unite together; and a very languid inteſtine Motion, by bringing Particles nearer to one another, which otherways would not have come together, conduces to encreaſe the Combination of Particles.

We have now ſeen how Nature has provided for the Formation of the Bile in the Blood, which paſſes thro' the Meſenterick Artery. We ſhall next conſider what Care is taken of that

which is conveighed by the Celiack Artery to the Liver: For it ſeems it was neceſſary to ſend a larger quantity of Blood to the Liver, than could be diſpoſed off thro' the Inteſtines. Part of the Blood of the Celiack Artery is ſpread upon the Stomach and Caul, and its Velocity diminiſhed, as we have ſeen in the Inteſtines; but ſtill all the Blood, which theſe parts could receive, was not ſufficient for the Liver, and there was no more room for the diviſion and expatiating of the Veſſels thro' ſuch a large Space as the Meſentery, and a long Tract of Guts. How therefore muſt the Velocity of the reſt of the Blood (to which the Inteſtine Motion is always proportional) be abated? Nature has here another extraordinary Contrivance, ſhe empties the Blood entirely out of the Veſſels into a large

ſpongy

ſpongy Bowel, or rather Ciſtern provided for that intent and purpoſe. I know not the Dimenſions of the Splenick Artery, but the Circumference of the Celiack being $\frac{1}{2}$ an Inch, or ,5, its Square is ,25; and therefore the Square of the Splenick, which is a Branch of it, cannot be above ,18. Now the Dimenſions of the Spleen are 6 Inches in length, 3 or 4 in breadth, and 2 in thickneſs. I ſhall therefore make this eaſy Suppoſition for the more ready Calculation, that it is a Cylinder of 2 Inches Diameter, and therefore the Square of its Circumference being 36, the Blood muſt move 200 times ſlower in the Spleen, than in the beginning of the Splenick Artery: and is longer before it gets to the Liver, than that which paſſes thro' all the Inteſtines. Is not this the long ſought for

*The Uſe of the Spleen.*

for uſe of the Spleen? So productive is one ſimple Truth of many others.

From all this Art and Contrivance it is evident Demonſtration, that the Intent of Nature was to diminiſh the Velocity of the Blood, and that ſuch a ſlow Motion was abſolutely neceſſary for the ſecerning of the Bile in the Liver. If the Humours which are ſeparated by the Glands are at all times and places the ſame in the Blood, and not formed after the manner demonſtrated, what need was there for diminiſhing ſo conſiderably the Velocity of the Blood? let the Blood move faſt or ſlow, they would be always the ſame, and always in an equal aptitude to be ſecerned.

*The Proportion of the Bile to the reſt of the Blood.*

The Particles, which compoſe the Bile, bear a very ſmall Proportion to the reſt of the Blood, as is evident

evident from the great quantity of Blood that is carried to the Liver, and the ſmall quantity of Bile that is ſeparated by it. In a large Dog, whoſe *Ductus Cholidochus* was near as big as a Man's, I could never gather above two Drachms in an Hour. Now there is throwm into the *Aorta* every Hour about 4000 Ounces of Blood: and it appears by the Proportions of the Arteries, that the Meſenterick and Celiack are to the reſt, as 1 to 8; and therefore 500 Ounces of Blood: are carried every Hour to the Liver. And ſince only two Drachms of Bile are ſeparated from it, the Bile muſt be to the Blood, at leaſt, as one is to two thouſand. It is by reaſon of this ſmall Proportion of the Bile to the Blood, that it was ſo neceſſary to allow ſo much time for the Attraction of the Particles which form

the Bile. From this Contrivance of the *Porta*, the Bile receives another Advantage, not leſs conſiderable than the Diminution of the Velocity of the Blood: and that is the Blood paſſing thro' ſo many different parts before it comes to the Liver, parts with the greateſt part of its *Lympha*, by which means the Particles, that compoſe the Bile, approaching nearer to one another, are by their mutual Attraction ſooner united. And the conſideration of theſe two Contrivances does highly confirm the truth of this Theory of Secretion: For the Diminution of the Velocity of the Blood, and the Subtraction of the *Lympha* can agree in no other end, than the uniting of the Particles of the Bile.

What has been ſaid concerning the Bile, does ſo evidently prove this Doctrine of Secretions, that there

there ſeems to be no room to doubt of it, even tho' we could not clear the like Difficulty, as to the Formation of the Seed. Yet here again, we meet with another Manifeſtation of the truth of it, and we find Nature purſuing the ſame Intentions, tho' in a different manner, the Structure of the parts not allowing either of the former Contrivances.

*Of the Secretion of the Seed.*

The Blood is carried to the Teſticles by the Spermatick Arteries; which, contrary to the conſtant Method of Nature in framing the other Arteries, are ſmalleſt, where they ſpring from the Trunk of the great Artery, and immediately dilate to a conſiderable bigneſs: which evidently ſhews, that there could be no other deſign in it, but to retard the Velocity of the Blood. We cannot ſuppoſe that the only Intention

tion was, that a ſmall quantity of Blood might go to the Teſticles: becauſe then there had been no occaſion for giving the Artery a different Figure from all others; that narrow Orifice would have been ſufficient of its ſelf for that purpoſe, which the wideneſs of the Artery immediately afterwards does neither hinder nor further. The Orifices of the Spermatick Arteries were ſo ſmall, that I could not meaſure them, when I took the Dimenſions of the other Arteries; and yet they are hardly gone from the *Aorta* before they dilate as big, if not bigger than one of the Lumbals, which is 434, 2: Now if we ſuppoſe their Orifices to be each 17, 3, then the Blood will move 25 times ſlower, where the Artery dilates, than it does at its Orifice. Again, we conſtantly find that all the parts of

the Body are ſupplied with Blood by ſmall Arteries from the neareſt Trunks. If this Method had been obſerv'd in ſending the Blood to the Teſticles, they had received their Arteries from the Iliacks; and they had ran but a little way, before they had come to the end of their Journey. But inſtead of this, two ſmall Arteries are made to ariſe from the *Aorta*, a little below the Emulgents, and to march above a Foot before they come to the Teſticles. Now if we conſider that the Velocity of the Blood in the Spermatick Artery, is 25 times ſlower than it is at its Orifice, that is, in the *Aorta*; and that the Velocity of the Blood in the Iliacks, can be but a very little leſs than it is in the *Aorta*, where the Spermaticks ariſe; the Blood muſt move 25 times ſlower to the Teſticles, than if it had gone

the ordinary manner from the Iliacks: and becauſe the Space it runs thus ſlowly, is at leaſt ſix times longer than if it had gone from the Iliacks; therefore it muſt be 150 times longer in going to the Teſticles, than if it had gone according to the common Courſe of Nature. So that the inteſtine Motion of the Blood is not only allayed, but ſufficient time is afterwards allowed the Particles, which are to compoſe the Seed, to attract and coaleſce before they arrive at the Teſticles.

*Some Objections anſwered.*

Perhaps it may be ſaid, that the *Mucus* of the Noſe, and the Wax of the Ear are ſeparated, where the Blood is not ſo languid as their Viſcidity ſeems to require: But I anſwer, that they are Fluids which fall into open Paſſages, where the Air having free Admiſſion, carries off part of their aqueous Fluid; and the

the Remainder becomes thick, as the *Serum* of the Blood does, when heated. Beſides, we muſt remember, that tho' the Coheſion of the Particles depends upon their Figures, yet the Force by which they attract one another, is likewiſe in Proportion to their Solidities. So that Particles of equal Magnitudes, and ſimilar Figures may cohere equally ſtrongly, yet the moſt ſolid will ſooneſt unite. Hence it is, that of two Fluids equally viſcid, the heavieſt may be ſeparated in Glands nearer to the Heart than the other; and that two Fluids of different viſcidities may be ſeparated at the ſame vicinity to the Heart, if the quantity of the Contacts of the Particles be ſuch, as will make amends for their want of Solidity.

Moſt, if not all the Secretions contain a greater or leſſer Proportion

of the aqueous Fluid, which makes them more or leſs viſcid; yet that which contains the greateſt quantity, may conſiſt of Particles endued with a very ſmall and ſlow attractive Force: and conſequently ſuch a Fluid cannot be ſeparated by any Gland ſo near the Heart, as that which has a leſs Proportion of the aqueous Fluid, and which conſiſts of Particles endued with a ſtronger attractive Force; and this laſt Fluid may be much more viſcid than the other, whoſe Particles are more diluted by the watry Fluid. Now how it comes to paſs that a greater or leſſer Proportion of the aqueous Fluid is ſeparated in any Gland, I ſhall ſhew in the ſecond part of this Diſcourſe.

But that the different Viſcidities of the Secretions do not depend only on the greater or leſſer Proportion

tion of the aqueous Fluid, is evident from the foregoing Propoſitions; unleſs any one can ſuppoſe that the Blood conſiſts only of one ſort of Particles: which Suppoſition, beſides that it contradicts matter of Fact, can never account for the Secretion of ſo many different Fluids. And that the Diverſity of the Attractions in the Particles is the Reaſon, why various Velocities of the Blood, and diſtances from the Heart, are required for ſecerning of different Liquors, is moſt evident from what has been ſaid concerning the Bile, and the Seed. If only a greater or leſſer Proportion of the aqueous Fluid had been requiſite for ſeparating of different Sorts of Fluids, that might have been done any where, as ſhall be ſhewn afterwards; and Nature had not been put to

ſo many Shifts and Contrivances, as we have already ſeen.

*Some Fluids may be ſecerned any where.*

As ſome Fluids are only to be ſeparated in certain Velocities of the Blood, and at certain diſtances from the Heart; ſo there may be others that may be ſeparated any where, and in any Velocity of the Blood. Theſe are ſuch as conſiſt of Particles always in an equal Aptitude to be ſecerned, and tho' ſome of them may contain ſeveral ſorts of Particles, yet the Nature of theſe Fluids does not depend upon the Attraction and Coheſion of their Particles. Such a ſort of Secretion is the *Lympha*, which is a watry Fluid ſecerned in all parts of the Body, for making the Chyle more liquid. If it be ſaid, that ſince the *Lympha* might have been ſeparated any where, and that it ſerves only to dilute the Chyle, that there ought

to have been a particular Gland ſome where for it in the *Abdomen*, as being the more proper place: I anſwer, that a large quantity of *Lympha* was neceſſary for diluting the Chyle, as appears by the numerous *Lymphedu&ts*, which diſcharge themſelves into the *Receptaculum Chyli*, *Du&tus Thoracicus*, and Subclavian Veins. And if ſuch a quantity had been ſeparated by a Gland or Glands in the *Abdomen*, appropriated to that uſe, they muſt have had very large and conſiderable Arteries. The Liver has $\frac{1}{4}$th part, and the Kidneys near $\frac{1}{5}$th more of the whole Blood, which paſſes thro' the *Aorta*; and if the Lymphatick Glands had had $\frac{1}{5}$th part more (which is the leaſt they could have had) theſe three parts would have had near one half of the Blood, and the other half muſt have ſerved all

*Why the* Lympha *is ſecerned in ſeveral places.*

all the reſt of the Body: which would have been a very unequal Diſtribution of the Blood. Beſides, Nature is always very ſimple and frugal in her Operations; ſhe never is at any unneceſſary trouble: and I will ſhew in the ſecond part of this Treatiſe how the *Lympha* may be drawn off, by Glands appointed to ſeparate other Fluids; ſo that for this Operation ſhe makes no Part, is at no expence of Blood: but ſhe muſt have been at a very great one, if ſo much *Lympha* had been drawn off by appropriated Glands.

*Of the Secretion of Animal Spirits.*

I take the animal Spirits to be another Fluid of this kind. They, undoubtedly, conſiſt of by far the ſmalleſt Particles in the Blood, as appears by the minuteneſs of their ſecerning Glands; and therefore they not being formed by the Co-

heſion

heſion of other Particles, might have been ſeparated any where. Yet the Animal Oeconomy receives a great Advantage by the diſtant Station of the Brain from the Heart; for if it had been placed nearer, and received the Blood, ſtill divided into its ſmalleſt Particles, by the force of the Air in the Lungs; ſuch Particles might have entred the Glands, as, afterwards cohering to one another, might have obſtructed ſuch extremely narrow Channels. Now the Brain being placed at ſuch a diſtance, the Particles, that by their attractive Power form Corpuſcles, will have ſufficient time to coaleſce, and their Magnitude will hinder their entring into the Glands. For if it ſhould happen, that theſe Particles ſhould enter the Glands, and there unite together, they would then obſtruct the Paſ-

ſage

ſage to the Nerves, and produce Apoplexies, Palſies, Coma's, *&c.*

The Particles, of which the animal Spirits conſiſt, being of ſuch extreme Fineneſs, their quantity can bear but a ſmall Proportion to the other Fluids in the Blood; and conſequently there was a neceſſity of a prodigious Number of Glands to ſeparate them from the Blood; and this is the Reaſon of the great Bulk of the Brain.

*Of the Number of different ſorts of Particles in the Blood.*

The Operations of Nature are always the moſt eaſie and ſimple. Now how much more eaſie is it to have the ſeveral Secretions formed after the manner which has been demonſtrated, than to ſuppoſe as many different ſorts of Particles in the Blood, as there are Fluids ſeparated from it? It is not eaſie to determine, how many different ſorts of Particles are in the Blood. Indeed,

deed, Phyſick ſeems in nothing ſo defective, as in the Knowledge of the Nature of the Blood. But if the ſame Pains had been beſtowed upon it in a Mechanical Way, that have been, in vain, ſpent in ſearch of its Principles by Chymiſts; we had long e'er now had a more perfect Knowledge of its Nature, than ever we can have by Chymiſtry: which can only ſhew how, by Art, its parts may be altered, not what parts it contains.

A few different ſorts of Particles variouſly combined, will produce great Variety of Fluids, ſome may have only one ſort, ſome two, ſome three, or more; and perhaps the aqueous Fluid is the common Baſis of all the Secretions. If we ſuppoſe only five different ſorts of Particles in the Blood, and call them a, b, c, d, e, their ſeveral Combinations,

nations, without varying the Proportions, in which they are mixt will be theſe following.

ab: ac: ad: ae:
bc: bd: be: cd:
ce: de: abc: adc:
bdc: bde: bec: dec:
abcd: abce: acde: abde:
bcde: abcde.

But whether there are more or fewer in the Blood, I ſhall not determine.

*Of the Operation of Medicines, which alter the quantity of the Secretions.*

The manner that Medicines operate, which encreaſe or diminiſh the quantity of any Secretion, is both eaſie and obvious from what has been ſaid. There is no need of giving Medicines Commiſſions for ſearching and opening the Sluces of particular Glands; nor have they a general Power to attenuate and

and diſſolve all the Coheſions of the Blood, for then we might ſtill ask why their Operations appear only on one ſort of Glands? Why does Jallap carry the diſſolved Humours thro' the Glands of the Inteſtines, rather than any other? Why does Mercury ſalivate, or Nitre force Urine? All Theories of Secretions have laboured at this point, which naturally diſcloſes its ſelf in this.

The ſeveral Humours being formed by the different Coheſions of the Particles of the Blood, the quantity of Humour ſecerned by any Gland, muſt be in a Proportion compounded of the Proportion, that the Number of the Particles, cohering in ſuch a manner, as is proper to conſtitute the Humour which paſſes thro' the Gland, bears to the Maſs of Blood, and of the Proportion

tion of the quantity of Blood that arrives at the Gland. And hence it follows, that where there is a determined quantity of a certain Humour to be ſeparated, the number of the Particles that are proper to compoſe the ſecerned Liquor, muſt be reciprocally proportional to the quantity of Blood that arriveth at the Gland: and therefore if the quantity of the Secretion is to be increaſed, the Number of the Particles is to be increaſed; if the Secretion is to be leſſened, the Number of the Particles, that are proper for ſuch a Secretion, is to be leſſened in the ſame Proportion. Medicines therefore which can alter the Coheſions and Combinations of the Particles, can either increaſe or diminiſh the quantity of any Secretion. Thus for example, ſuppoſe the Humour, which paſſeth thro' the

the Glands of the Inteſtines to be compoſed of three or four ſeveral ſorts of Particles, that Medicine which will eaſily cohere to theſe Particles, and cohering increaſe their mutual Attractions, ſo as they unite in greater Numbers at, or before they arrive at the Inteſtines, than they would have done if the Medicine had not been given, muſt neceſſarily increaſe the quantity of Humour, which paſſeth thro' the Glands of the Inteſtines, if the quantity of Blood which arrives at the Glands is not diminiſhed in the ſame Proportion, as the Number of the Particles is increaſed. After the ſame manner do Diureticks, Sudorifick, and Medicines, which promote all other Secretions, operate.

*Specifick Purges.*

If Medicines, which encreaſe the quantity of any Secretion, operate by uniting to, and augmenting the

attractive Force of the Particles, which compose the Humours to be secerned: may not the Particles of some Humours, sooner, more easily, and strongly unite to the Particles of some sort of Medicines, than to another sort? And consequently, may not different Humours require different purgative Medicines to carry them off thro' the Glands of the Intestines? And does not this reestablish the Doctrine of Specifick Purges, confirmed to the Ancients by Experience and Observation, but rejected by the Moderns thro' a false Philosophy?

*The Knowledge of Secretion necessary for the understanding the Nature of Diseases*

The Animal Body is nothing but a Machine, whose Actions and Motions are all performed by Fluids, secerned from the Blood, and Secretion is the Spring of all the animal Functions. By its means the Heart beats, the Blood circulates, the

the Limbs are moved, and the Aliments concocted and digested, and in a word, the whole Animal Oeconomy, and Life depend upon it; the Blood its self seeming to have little other use, besides the recruiting and renewing the secerned Liquors. I say therefore, since Life and Health depend upon the Secretions; so likewise must all Diseases, which are said to be universally in the Blood, and many of those which affect particlular parts. If the quantity and quality of all the Secretions are such as are proper and useful for the several Purposes, for which by Nature they are intended, how is it possible but that the whole Animal Oeconomy must be in right Order, and that Body in a good State of Health? Unless we can suppose an Error in the first Contrivance of the Body; a Suppositi-

on no Man in his Senſes can make. But if the quantity of any Secretion exceeds its due Bounds, what Diſorders it makes is evident from a Diarrhæa, Diabetes, Epiphora, Sweatings, *&c.* If the quantity of any Secretion falls ſhort of what it ought to be, the Effects are of no leſs pernicious Conſequence, as appears from a Suppreſſion of Urine in the Kidney, from the Jaundice and a Stoppage of Perſpiration. And that the quality of the Secretions altered do likewiſe create great Diſorders, is obvious from the Pains of the Colick, of a Diarrhæa, and Dyſentery, from the Sharpneſs of Urine, which ſometimes produces Ulcers in the Bladder and Kidneys; and even the Spittle is known to corrode the Mouth. I have choſen to give moſt Inſtances of ſuch Secretions, as are pro-

properly Evacuations, becauſe their Effects are apparent to every body, and cannot poſſibly be ſaid to be only a Notion. But if the Alteration of thoſe is of ſuch ill Conſequences, what Effects muſt an undue quantity, or the vitiated Quality of theſe, which are retained in the Body, and employed about the neceſſary Functions of Life, produce? The Diſorders they create, are not ſo evidently the Effects of their ill State, tho' by a juſt reaſoning, we may ſometimes deduce them; and therefore a right Notion of Secretion muſt be of the greateſt uſe and Importance, for the underſtanding of moſt Diſeaſes.

*Of a Diabetes.*

I ſhall only inſtance in a Diabetes, and from this Doctrine of Secretion explain the Nature of that Diſeaſe hitherto unknown. The Symptoms, which precede a Diabetes,

are little wandring Pains, and frequent Twitchings of the Tendons. Theſe are followed by a profuſe Evacuation of a clammy, ſweetiſh Urine, as if Honey were diſſolved in it; which is conſtantly attended with a Thirſt, quick Pulſe, Faintneſs, and loſs of Strength: all which depend upon the Flux of Urine, and increaſe and diminiſh in the ſame Proportion with it. The evident Cauſe of this Diſtemper is an habitual drinking of ſtrong Liquors, and the more ſpirituous they are, the ſooner and more violently they bring it. But a Diabetes is not always cauſed by an habitual drinking of ſtrong Liquors, for ſometimes it proceeds from ſome internal and latent Cauſe. However, the Nature of the Diſeaſe is always beſt known, by conſidering what

what effects the evident Cauſes of it produce in the Body.

By an habitual drinking of ſtrong Liquours, it comes to paſs in proceſs of time, that the *Serum*, or thin part of the Blood, contains a large Proportion of a ſpirituous Fluid; or that part of the Serum, which ſhould be Water, is for the greateſt part Spirit. Now the Salts of the Urine or Blood, will not diſſolve in vinous Spirit, that is, the Particles, of which the Salts conſiſt, are more ſtrongly attracted by one another, than they are by ſuch a Fluid, as by Experiments it appears. And therefore the Quantity of Salts in the Blood, will be daily increaſed, and circulating thro' the Capillary Veſſels, muſt irritate the fine Fibres, and cauſe little Pains and Twitchings all over the Body. But when the Serum is full of theſe

Salts, the distance between them and the Globules of the Blood will be less; and consequently they will attract the Globules of the Blood, more strongly than the Globules attract one another; and the Globules, or red Part of the Blood, will be dissolved and diffused thro' the Serum of the Blood. And this again is confirmed by Experiments; for nothing does render the red part of the Blood so Fluid, and keep it more from coagulating, when drawn in a Cup, than Urinous Salts and Spirits. When the Red part of the Blood is thus dissolved and united to its Serum, it will with the Serum be carried off thro' the Glands of the Kidneys, and being united to the Salts, will alter their Figures and Properties, as Litharge and Corall do the Salts of Vinegar, giving them a sweet Taste.

All quick Evacuations of the Veſſels muſt diminiſh the quantity of Fluid, ſeparated in the Glands, as will be ſeen in the following Treatiſe about the Quantity of Blood; and therefore the greater quantity of Urine is voided in a ſmall time, the leſs *Saliva* and animal Spirits will be ſecerned by their reſpective Glands: and conſequently Thirſt, Faintneſs, and loſs of Strength will increaſe, as the quantity of Urine excreted increaſeth.

This being the State of the Blood, it is evident that the Indications of Cure, are to diſſolve the Coheſions of the Salts with the Blood, and to carry them off by Urine. Theſe can be anſwered by nothing ſooner or better than Waters, which are therefore to be drunk in large quantities. And of all Waters, thoſe which have a Tincture of

Lime

Lime are beſt, becauſe Lime does ſtrongly attract Urinous Salts.

I could ſhew the uſefulneſs of this Doctrine, in explaining ſome Symptoms of Feavers, Rheumatiſms, Small-Pox, and ſome other Diſeaſes, which are not thought to depend upon Secretion; and from thence deduce what things are hurtful, and what uſeful in the ſeveral Methods of curing them: but that would carry me beyond my preſent Deſign, and perhaps may more fully be illuſtrated ſome time hereafter. I will only take notice, that from this Theory, we have a plain and eaſie Account of the Thickneſs of the Blood in Rheumatiſms; for it is known, that this Diſeaſe ariſing generally from a Cold, the Orifices of all the cuticular Glands are extremely contracted, ſo that ſcarce any Fluid, but the aqueous can

*Of Rheumatiſms.*

can pass them: and therefore the other Particles, by the Diminution of the aqueous Fluid being brought nearer to one another, will attract and cohere more strongly. And this Cohesion will be greatest in the Extremities, where the Motion of all the Particles is near equal by the 11th Proposition. And does not this evince the Necessity of diluting the Blood in the Cure of Rheumatisms? This equal Celerity of the Particles of the Blood in the Extremities, is likewise the Reason why the Concretions of the Gout are formed there; unless by frequent Debauches, or a decay of Nature, the Motion of the Blood becomes so languid, that these Particles easily attract one another in the Blood Vessels of the Bowels, where I have shewn that the Motion of the Blood is also very slow: *Of the Gout.*

and then ſuch Remedies as warm and increaſe the inteſtine Motion of the Blood, and thereby diſturb the Attraction of the gouty Particles, relieve the Bowels, and ſend the peccant matter to the Extremities again. To this Attraction of the Particles in the Urine, is owing the Formation of Gravel and Stone in the Kidneys and Bladder, and the Nucleus of the Stone in the Bladder, being almoſt equally ſurrounded every where with the Fluid of Urine, its Attractions are almoſt every where equal; and therefore the Stone is made up of ſo many parallel Shells or Laminæ. Now from this it demonſtratively follows, that copious and liberal drinking muſt neceſſarily prevent the growth of both: For by that the attractive Particles are removed at a diſtance too great to attract

*Of the Stone.*

attract one another. Provided always that the Drink be such, as is not highly saturated with Particles, which easily and strongly attract one another; what these Drinks are, they, who know the Nature of the Liquors which are commonly drunk, will easily understand.

*The Operations of Medicines explicable by Attraction.*

As this Principle of Attraction will account for most Diseases; so I doubt not, but that by it likewise the Operations of all sorts of Medicines may be explained. For example, Medicines which thicken the Blood, are such as consist of very small Particles, and endowed with a strong attractive Force, by which easily cohering to the Globules of the Blood, they increase their Attraction to one another, and so produce a Coagulation, or at least a thickening of the Blood. On the contrary, if a Medicine consists of such

ſuch Corpuſcles, as will eaſily unite with the aqueous Particles, and increaſe their Attraction; ſo that they attract the Globules of the Blood with a greater Force, than theſe Globules attract one another, then will the Globules recede from one another, be diffuſed thro' the Serum, and the Coagulum be diſſolved. A Gonorrhea is undoubtedly produced by a very active Salt, which being ſtrongly attracted by the Humour in the Glands, and uniting to it, like the Acids of Salt and Vitriol to Mercury in the Preparation of Sublimate, forms a very *virulent pus*, which corrodes the Veſſels, and produces Ulcers. And as Sublimate loſes its corroſive Faculty, by the Addition of more Mercury, which ſtrongly attracts its acid Salts; ſo Mercury mixt with the Blood, attracts the acid

*The Operation of Mercury.*

acid Salts of the Pox, and uniting to them, carrys them off, either bp Stool, Spittle, or otherwiſe. This Power, by which Mercury attracts acid and ſharp Salts, is the Reaſon why Cinnabar is ſo good a Medicine in fixt and vagrant Pains, as in a Rheumatiſm: for the Urine of Rheumatick Perſons is found upon Examination, not to contain its due quantity of Salts, which therefore being retained in the Blood turn acid, and produce Pains.

Now, who can doubt of the Truth of a Principle ſo ſimple, and yet which like a Maſter-key opens Works of very different Contrivances, and diſcloſes an Uniformity in all the Operations of Nature; ſo that every one may ſee and read the ſame Thought and Hand in the Contrivance, and framing of every part of the Univerſe. By it we ſee

the

the Reaſon why the Branches of all the Arteries in the Body, have the Sum of all their tranſverſe Sections greater than the tranſverſe Section of the *Aorta*; for if it had been otherwiſe, there could have been no Mucilage ſeparated for the eaſiy Motion of the Joints, without ſuch a Structure as the Spleen at every Joint, where this Mucilage was neceſſary. By it the Reaſon not only of the general Structure of the Veſſels is demonſtrated, but likewiſe the Neceſſity of the Frame and Situation of the particular parts, as of the Lungs, Spleen, *Porta*, and of all the Glands. By it the Nature of the Blood and all the Secretions may be explained. By it the whole animal Oeconomy, and all its Diſorders, the ſeveral Diſeaſes incident to the Body, the Nature of their Remedies, and the ways

ways of their Operations may be accounted for. This is that grand Principle, by which all the Particles of matter in this Planet are actuated. By which, but with a different force, all the Planets are carried round the Sun; and as the projectile Velocity of the Planets, adjusted to the Sun's Attraction, causes them to move in their several Orbits; so the Velocity of the Blood, adapted to the Attraction of its Particles, causes the several Humors to be secerned at certain distances from the Heart by their respective Glands.

I shall now proceed to the second thing I proposed to shew; which is, *The manner whereby the several Fluids, after they are formed in the Blood, are separated from it by the Glands.*

This does depend intirely upon the Figure and Structure of the Glands; which must be therefore first determined. As Truth when plain and evident does of itself dispel all false Opinions, so the true Structure of the Glands being once demonstrated; there will be no Occasion to refute the Doctrine of Ferments; nor the Hypothesis of Tubes differing as to the Figures of their Orifices, both which have been several times demonstrated to be false.

That the Glands are nothing but Convolutions of small Arteries, the greatest and most accurat Anatomists of this Age, *Malpighius*, *Bellini*, and *Nuck* have discovered. And indeed that all the Vessels of the Body, in which the Liquors are continually moving, can have

no

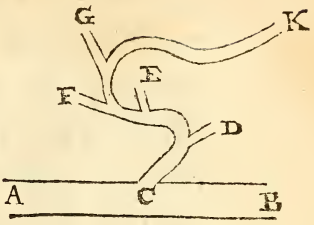
no other than a cylindrical or Conical Form, is demonſtrable from the Nature of Fluids, whoſe Preſſure is always perpendicular to the Sides of the containing Veſſel, and equal at equal Heights of the Fluid: If therefore the ſides of the Veſſels are ſoft, and equally yeilding every where (ſuch as are all the Tubes in the Body of a *Fœtus*) they muſt by the Preſſure of their contained Fluid, be equally every where diſtended; and conſequently the Section of ſuch a Veſſel perpendicular to its Axis muſt be a Circle, and therefore the Veſſel muſt be either a concave Cone or Cylinder, or at leaſt ſuch a Figure whoſe tranſverſe Section is a Circle.

The Circular Orifices therefore of the Glands can only differ in Magnitude, and all ſorts of Parti-

cles of a leſſer Diameter than that of the Orifice of the Gland may enter it; ſo that without ſome farther Contrivance, that Fluid which contains the biggeſt Particles, muſt likewiſe conſiſt of all the Particles of all the other Secretions; neither could any Fluid thicker than the Blood be ſeparated from it, becauſe of the great Proportion of the aqueous Fluid, whoſe Particles being vaſtly ſmaller than any other; and inviſible to the beſt Microſcopes, muſt enter all the Glands, and be mixt with the ſecerned Fluid.

How this inconveniency may be prevented, and how the Particles of any ſize may either be ſeparated by themſelves, or with any aſigned Proportion of the aqueous Fluid, or of other leſſer Particles, I ſhall now endeavor to ſhow.

ſuppoſe




Suppoſe A B to be a ſmall evaneſcent Artery, and that the Particles of the leaſt ſize were to be ſeparated from the reſt. From the ſide of the Artery muſt ariſe the Gland or Tube C K, whoſe Orifice at C is ſuch as is capable of admitting only Particles of the leaſt ſize, together with the *Aqueous* fluid, theſe therefore will be ſeparated from all the other Particles of the Blood, and the Tube C K being a Cylinder, they will paſs to its further end K, which is ſuppoſed to be the Excretory Duct of the Gland.

If the Quantity of the *Aqueous* fluid, ſeparated with the leaſt Particles muſt be diminiſhed, that ſuch a fluid as is requiſite, may paſs thro' the Excretory Duct K, from

the Tube C K, you muſt imagine that ſeveral other ſmaller Canals go out, as at D, E, F, G, whoſe Orifices are ſo ſmall, that they admit no other Particles beſides thoſe of the *Aqueous* fluid to paſs thro' them; and therefore as the leaſt Particles, together with the *Aqueous* fluid paſs along the Tube C K, the *Aqueous* fluid muſt conſtantly be diminiſhed, the Quantity of the leaſt Particles ſtill remaining, the ſame can paſs no where, but thro' the Excretory Duct K; and this Diminution of the *Aqueous* fluid will be always according to the Number of the Canals D, E, F, G, that is in Proportion to the Length of the Tube C K, and therefore according as the Gland is longer or ſhorter, ſo the more or leſs *Aqueous* fluid will paſs thro' the Orifice of the Excretory Duct K, and conſequently

ſequently the ſecreted Fluid upon this Account be thicker or thinner.

If the Particles of a middle ſize, between the biggeſt and the leaſt, are to be drawn off from the reſt of the Blood. Let the Orifice at the Gland C be juſt ſo big as to admit theſe Particles, and not any of thoſe that are bigger: Theſe Particles therefore, together with the *Aqueous* fluid, and all leſſer Particles will paſs thro' the Orifice C, but if the Canals D, E, F, G, are big enough to receive all the other Particles, and too narrow to admit the Particles that are to be ſeparated; it is evident, that thoſe Particles muſt arrive at the Excretory Duct K, with what Proportion of leſſer Particles is required.

Thus we ſee how any ſort of Particles may be drawn off, either by themſelves, or mixt with any

others in any Proportion, and this is done in the moſt ſimple manner, only by Arteries, for C K is only a ſmaller Artery, ſtraight, ſpiral, or otherwiſe contorted, and D, E, F, G, are again Arteries ſmaller than it, and if any of theſe are ſo ſmall, as to admit only Particles of *Serum*, they conſtitute lymphatick *Veſſels*; from thence it is that we find *Lympheducts* to ariſe in great Numbers from thoſe Glands that ſeparate thick Humours, as from the Teſticles, Liver, *&c.*

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## *Of the Quantity of Blood in the Humane Body.*

*How the Quantity of Blood has been determined.*

I Know not upon what grounds *Phyſicians* and *Anatomiſts* have generally determined the Quantity of Blood in the Humane Body, to be

be between fifteen and twenty five pound Weight. All that I can find is the large Quantities of Blood voided by Persons dying of violent *Hæmorrhagies*; so that according to their several Observations, some have ascribed a greater, and some a smaller Quantity of Blood to the Body. Dr. *Moulin* has allotted by much a smaller Quantity than any, and gives us the Method by which he determin'd it in the *Philosophical Transactions*. He says, That in a Sheep, which alive, weigh'd 118 *lib.* he found by bleeding it to death, that it contain'd $5\frac{1}{4}$ *lib.* of Blood, which is less than $\frac{1}{22}$ part of the Weight of the Sheep. That in a Lamb weighing $30\frac{1}{2}$ *lib.* when living, there was but $1\frac{1}{2}$ *lib.* of Blood, which is about $\frac{1}{20}$ part: Now upon the Supposition, that a Man's Blood bears the same Proportion

*How Dr.* Moulin *did determine it.*

portion to his Weight, as that of the Lamb's (which is the greateſt) had to its Weight, it will follow, that the Quantity of circulating Blood in a Man, weighing 160 *lib.* will not exceed 8 *lib.*

*Neither of theſe Ways juſt.*

Theſe Eſtimations (tho' widely different from one another) are both made from the Quantity of Blood voided at an open *Veſſel*, and they are both founded upon this Suppoſition, that almoſt all the blood in the Body runs out at the Wound; a Suppoſition I can by no means allow to be true, and which I ſhall evidently ſhew to be falſe. For ſuppoſe the right external *Iliack* Artery cut aſunder, ſo as that the Blood may freely flow out of the Wound: How can the Blood which is in the right Leg below the Wound, be emptied? It is cut off from the reſt of the Blood above, which

which ſhould drive it forwards, and all the Aſſiſtance it can have from collateral *Branches*, which communicate with it can be but very little, becauſe they themſelves can receive but a very ſmall quantity of *Blood*, the *Blood* running all to the Wound, where it finds the leaſt Reſiſtance. The Arteries in the *Leg* can beat no longer, becauſe the Pulſe depends upon the Quantity of *Blood* thrown into them every Syſtole of the Heart, which in this Caſe is nothing, and theſe being the only regular Cauſes of the Motion of the *Blood*, the *Blood* muſt ſtagnate in the Crural *Veſſels*. All that can be ſaid is, that the great Arteries will once contract, and may perhaps have ſome ſmall *Vibrations* afterwards, by which they will thruſt the *Blood* into the capillary *Veſſels*, and their convulſive

ſive Motions will ſqueeze the *Blood* forwards in the *Veins*; but when an Animal once falls into Convulſions by bleeding, it can bleed but little afterwards, the Motion of the Heart ceaſing; beſides we know, that neither all Animals, nor all Parts of an Animal are convuls'd upon bleeding to death: And tho' the great Arteries may contract, yet this Contraction muſt be very languid in the ſmall Arteries, which being innumerable, the greateſt part of the *Blood* will be lodg'd in them, there being nothing to drive it out of their contorted Channels, but it muſt ſtill remain in them, as likewiſe in the Fibres of the Muſcles, which appear of a red Colour, only upon the Account of the *Blood* contain'd within them, their Subſtance being naturally White. Again, tho' the right and left *Iliack* Arteries

do

do in the natural State receive an equal quantity of *Blood*; yet when a Wound is made in the Right, thro' which the *Blood* has an eaſie Paſſage, this muſt receive much the greateſt part of the *Blood* which comes down the *Aorta*, and conſequently the Circulation of the *Blood* muſt be very ſlow in the left *Leg*, and no more *Blood* can come from it, than what is thruſt out meerly by the Motion of the *Body*, or what flows naturally of its ſelf in the ſtrait and large *Veſſels*, as Fluids will do to come to an *Æquilibrium*; for the ſame Reaſon the aſcending *Trunk* or *Branches* of the *Aorta* can receive but a ſmall quantity of *Blood*, and therefore the Pulſe in the Arteries of the *Brain* muſt be very languid or none at all, upon which Account the Motion of the Spirits muſt ceaſe, and conſequently

ly that of the Heart. When the *Aorta* begins to be empty (which muſt quickly happen when the *Blood* runs out at a Wound of a large Artery) then the *Blood* having little or no Reſiſtance, will flow eaſily into the empty *Veſſel*, and a very ſmall Quantity of it will enter the Orifices of the Coronary Arteries of the Heart, the *Valves* covering them, and conſequently the Motion of the Heart muſt ceaſe for want of *Blood*.

*The greateſt Effuſion of Blood not from the largeſt Veſſel.*

It is for theſe two laſt Reaſons, that the larger the *Veſſels* are that are wounded, the ſooner the Animal dies; and if the *Aorta* it ſelf was cut aſunder, there would be a ſmaller Effuſion of *Blood* from it, than from a ſmaller Artery: For ſince it is the *Blood* in the *Aorta* that thruſts forward the *Blood* in the *Veins*, and makes it paſs from the

the *Vena Cava* into the right Auricle of the Heart; it is plain, that when the *Blood* in the *Aorta* is intercepted, the *Blood* will be no longer driven thro' the *Veins*, but will ſtagnate in them, no more of it coming to the Heart, than what by reaſon of the Fulneſs of the *Veins* flows into it, and conſequently the Heart throwing but a ſmall Quantity of it into the *Aorta*, the Circulation will be quickly ſtopt, both in the Aſcending and Deſcending Trunks, and there will be no greater effuſion of *Blood* than what can be contain'd in the great Artery which holds but little. Whereſoever the Wound is made, ſo long will the Animal live, as the great Artery keeps full, but whenever that begins to empty, the *Blood* in all its Branches muſt ſtop, and conſequently the Animal muſt die.

The

*The greatest Flux of Blood from the smallest Vessels.*

The *Vessels* of the *Animal Body* are not meer unactive Tubes, but as they may be gradually dilated, so they can gradually contract again; and as they cannot suffer any violent and sudden Stretching without breaking, so neither can they immediately contract upon any sudden Evacuation. And therefore when any great *Artery* is wounded, the *Animal* dies after a few Pulsations of the Heart, the great *Artery* being immediately emptied: But when a small *Artery* at a great distance from the Heart continues bleeding slowly, all the *Vessels* throughout the whole *Body* gradually contract, so that after many Pounds are evacuated, they may be as full as they were at first, and consequently the *Animal* not so much as faint, the *Vessels* in the *Brain* being still kept full, and the Spirits

Spirits driven forwards in the *Nerves*; nor can the Animal die till such time as the *Vessels* contract no more. It is for this Reason that we have no Observations, which give account of such large effusions of Blood, at Wounds of the great Arteries, as we have from the small *Vessels* of the Nose, and from the *Hæmorrhoides*; and therefore Doctor *Moulin*'s Determination of the Quantity of the whole Mass of Blood, which is calculated from the Quantity, voided at the Carotide and Jugular *Vessels*, is much less than what others from the Observation of *Hæmorrhagies* of small *Vessels* have determin'd it to be.

*The Reason of fainting upon any sudden Evacuation.*

This Contractive or Elastick Power of the *Vessels* is not equal in all Bodies; for in some it is greatly diminish'd by the Viscidity of the Blood, and the Obstruction in the

Fibres and Capillary *Veſſels*, and therefore ſome Men may die of a much leſs effuſion of Blood than others, who perhaps may have a leſs Quantity of Blood. It is for the ſame Reaſon that ſome Perſons faint upon opening a *Vein* of the Arm, whilſt others do not. If this Elaſtick Power of the *Veſſels* is ſtrong and great, then as the Blood is let out, the Arteries of the *Pia Mater* contract, and are kept full as well as the Coronary *Veſſels* of the Heart, and conſequently there is neither Blood nor Spirits wanting for performing the Motion of the Heart; but it happens juſt otherwiſe, where this Elaſtick Tone of the *Veſſels* is wanting, that is, to ſuch as have a ſoft and looſe Fleſh, a lax and cachectick habit of Body; and therefore when they require bleeding, it is convenient to

ſtop

ſtop the Blood at ſmall intervals, to give the *Veſſels* time to contract, before the full Quantity that is deſign'd be drawn off; and if they are ready to faint, the ſurprizing them, by throwing cold Water in the Face, to cauſe a ſudden Contraction, and the putting of them into an horizontal Poſture, that the *Veſſels* of the Brain may fill, and the Blood from all the depending Parts, have a more eaſie Reflux, does prevent it. It is the want of the ſame Energy of the *Veſſels* that cauſes ſome to faint upon any ſudden Evacuation by Urine, Stool, or any other ways.

*A Proof of this Reaſon.*

That this is the true Reaſon of fainting upon any ſudden or violent Evacuation, and not the drawing off of the Spirits (as is generally ſaid) appears not only from this, that ſuch as faint upon bleeding at the

Arm, do not faint upon Cupping, tho' the ſame, or a greater Quantity of Blood be drawn off this way, but likewiſe from the fainting of Perſons tapped for an *Aſcites*, if it happens, that too great a Quantity of the Waters is drawn off at once. None can ſuppoſe that the Spirits, which are in the extravaſated *Lympha*, have an immediate Influence upon the Nerves and Heart, that their Subtraction ſhould preſently drain the Nerves of Spirits, nor can any think, that the Spirits are ſo quickly ſpent, as immediately to ſuffer upon the account of the want of a Supply from an extravaſated Fluid: but the Caſe is this; In an *Aſcites*, the deſcending Trunk of the *Aorta*, and all its Branches being conſiderably compreſſed, the Blood muſt neceſſarily dilate the aſcending Branches beyond their

natural

natural Bigneſs; but, when the Waters are let out to any conſiderable Quantity at a time, the Blood has a more free Paſſage into the deſcending Trunk, the Sum of the Cavities of both Arteries is augmented, and the Quantity of Blood thrown out every Syſtole not being greater, the Arteries cannot be ſo much dilated, and conſequently the Pulſe becomes ſmall and weak, and the Spirits therefore are but ſlowly propelled thro' the Nerves, the Blood flows but in a ſmall quantity into the Coronary *Veſſels* of the Heart, and conſequently a Syncope muſt enſue, till the *Veſſels* can recover their Tone, and the Blood in all the Arteries comes to an *Æquilibrium*, and therefore it is neceſſary to rarifie the Blood, and rouſe the languid Motion of the Spirits by a Cordial.

That the Compreſſion of the deſcending Artery muſt throw a greater Quantity into the aſcending Branches is demonſtration, and that this Quantity is conſiderable, and does affect the whole Machine, is evident from the Fluſhing and Head-ach which ſome feel after a plentiful Meal, when the Stomach and Guts being loaded, preſs upon the deſcending Trunk, and contract its Cavity, which are the Cauſes why a greater quantity of *Blood* paſſes into the aſcending Trunks; on the contrary, if the Cavity of the deſcending Trunk ſhould be dilated, there will be a leſs Quantity of *Blood* thrown into the aſcending Trunks, and conſequently the Effects on the Animal *Body* muſt be at leaſt as ſenſible.

This contractive Power of the *Veſſels* ought to be duly conſider'd, before

before the leaſt Quantity of Blood be drawn in moſt acute, as well as chronick Diſeaſes; for I could eaſily ſhew how it may be loſt to a great Degree, in a few Hours. And in no Caſe whatſoever is the drawing off a large quantity of Blood at a time juſtifiable, ſince it may be done more ſafely, and to as good Purpoſe at ſmall Intervals. It is evident from the Theory of *Secretions*, that both the Quantity and the Quality of the *Secretions* may be altered by *Blood-letting*, and therefore when the *Blood* is upon a Ferment, and generates new Coheſions, of whoſe Nature we are ignorant, it is a Riſque, which without evident and cogent Reaſons, ought not to be run. But to return,

*The great Riſque in Bleeding, and the uncertainty of its Conſequences.*

If we give any Credit to the Obſervations of Phyſicians, we muſt

*A greater quantity of Blood proved from the Observations of Physicians.*

believe the Quantity of *Blood* in the Humane Body to be above 25 pound Weight. (*a*) *Rulandus* tells us, that he cured one of a bleeding at the Nose, after he had bled in one Day about Ten pound Weight. (*b*) *Petrus Borellus* observes, that a full bodied Jovial Taylor lost Ten pounds of *Blood* by the *Hæmorrhoides*, and that he cured him with the Syrrup of dried Roses. (*c*) *Sckenckius* quotes *Montanus* for one that voided Two pounds and more of *Blood*, by the Piles, every Day for forty five Days together, and was afterwards cured. (*d*) *Bartholin* says, that he saw one vomit sixteen pound of *Blood* without the least ill Consequence. And he takes Notice of

(*a*) Rulandus Curat. 57. Cent. x.
(*b*) Cent. iv. Obs. Lviii. (*c*) Lib. tert. Obs. clx. (*d*) Cap. de Corde.

one

one who bled forty eight pound in three Days by the Noſe, from *And. Argolus.* (a) *Sckenckius* has ſeveral Obſervations of profuſe *Hæmorrhagies* of the Noſe. He mentions a Nun of a thin Habit of *Body*, who by bleeding at the Noſe, ſpitting of *Blood*, and with Urine, voided eighteen pound of *Blood*; ſhe was cured by one Drachm of *Philonium Perſicum. Braſavolus* cured a Lady of a bleeding at the Noſe; the *Blood* which he weighed, beſides what fell upon the Ground, Linen and Cloaths, was eighteen Pound. *Marcellus Donatus* recovered one of a bleeding at the Noſe, who in two Nights and one Day, bled above twenty pound Weight, as he found by weighing it. And at laſt he tells us of one

(a) Lib. de capite Obſ. cccxxxiii.

who

who in ſix Days bled forty pound at the Noſe.

Now if the Quantity of *Blood* in the Humane Body was not conſiderably greater than its common Eſtimate, theſe Perſons could never have ſurviv'd ſuch profuſe effuſions of their *Blood.* All of them bled more than Dr. *Moulin* reckons to be in the Body, and many of them more, and almoſt double of the largeſt Quantity which is allow'd of by any: So that either we muſt deny theſe Matters of Fact, or we muſt own, that our higheſt Eſtimates of the *Blood* fall much ſhort of the true Quantity. Without doubt Men differ in the Quantities of their *Blood*, as well as in the Weight of their Bodies: But none of theſe above-mention'd are noted to have been of a full habit of Body except *Borellus*'s Taylor; and

and it is particularly ſaid of the Nun in *Sckenckius*, that ſhe was a ſpare and thin Woman, and that her bleeding could not proceed from a *Plethora.*

Having therefore ſufficiently proved, that the quantity of Blood in the Humane Body muſt be much greater than the common Eſtimation: I ſhall in the next Place endeavour to ſhew how much at leaſt it is.

By Blood I underſtand not only the Fluid in the Veins and Arteries, but likewiſe that in the *Lymphe-ducts*, *Nerves*, or any other *Veſſel* of the Body, becauſe they are all Parts of the Blood, ſeparated from it by the Force of the Heart, and many of them by the ſame Force return to it again; and therefore, when I ſpeak of the quantity of blood in the Body, I would be underſtood

*What is here meant by Blood.*

derſtood to mean the quantity of circulating Fluids, of what kind ſoever they be, at other Times I ſhall uſe the Word in its common Signification.

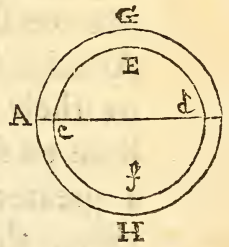
*The whole Body made of Veſſels and Fluids.*

I ſuppoſe the whole Body is nothing but *Tubes* or *Veſſels* full of *Blood* or *Liquors* ſeparated from it. This is now agreed on by all who underſtand the Fabrick of the Body, and is evident from nice Mercurial Injections of the *Veſſels*, and may be plainly ſeen by *Microſcopes*. *Leeuwenhoeck* ſays, That there ſeemed to be above 10000 Blood-veſſels in the ſpace of $\frac{1}{4}$ of an Inch ſquare. You cannot prick your Finger with the fineſt Needle but it wounds a Blood-veſſel. The Fibres of the Muſcles (which make by far the greateſt part of the Body) are full of Blood, and the Fibres of the Bones

Bones are not without their Fluid, as I ſhall ſhew afterwards.

I therefore conſider the *Veſſels* full of Fluids, as ſo many ſolid *Cylinders*, and the Coats of the *Veſſels*, as ſo many concave *Cylinders* of the ſame height, whoſe Proportion to one another may be thus determined. Let *A B G H* repreſent the circular Section of a Veſſel, of which call the Diameter *A B*, *a*, the Diameter *c d* of the Cavity, *a*—*b*. Circles being to one another as the Squares of their Diameters, the Square of the whole Section is $a^2$, the Square of the Cavity is $a^2 - 2ab + b^2$, which being ſubſtracted from the Square of the whole, there remains $2ab - b^2$ proportional to the annular Space *A B G H c d f E*, and conſequently

*The Proportion of the Fluids to the Veſſels.*



ly in a Body compos'd of such *Veſſels* filled with Fluids, the Fluids will be to the Solids, or Coats of the Veſſels as $a^2 - 2ab + b^2$ is to $2ab - b^2$.

*Several ſorts of Veſſels.*

Now if the whole Body was compoſed of Veins or Arteries, it were eaſie to determine the Quantity of Blood in the Animal Body. But we find, that the Coats of the Arteries have a greater Proportion to their Cavities, than the *Veins* have to theirs, and theſe again have a greater Proportion to their Cavities, than the *Lymphatick Veſſels* have to theirs, and there may be one Proportion of the Nerves, another of the Fibres of the Muſcles, and another of the Fibres of the Bones, all which ought to be known before the quantity of blood in the animal Body, can be exactly determin'd.

The

The thickneſs of the Coats of the Blood-veſſels may be thus exactly found: Slit a piece of a Blood-veſſel, and reduce it to the Form of a *Parallelogram*, then weigh it in Water, and by that means find the Weight of Water equal to it in bulk. This weight reduced to decimal Parts of an Inch call, $d$, and ſuppoſe the length of the *Parallelogram* equal to $e$, and its breadth $= c$, its thickneſs $f$. Then $d = e\,c\,f$ and conſequently $\frac{d}{e\,c} = f$ the thickneſs of the Coat of the *Veſſel*.

*The Proportion of the Blood in the Arteries to the Coats of the Arteries.*

Thus a piece of the *Aorta* of a Calf I found to be equal to 0.071897 parts of an Inch of Water, its length was 1.1, its breadth 1.28, and therefore its Thickneſs was 0.051. The Diameter of the Cavity of this Artery was 0.407. and conſequently $a^2 - 2\,a\,b + b^2$ equal to 0.165649, and $2\,a\,b - b^2$ equal to 0.093432,

0.093432, and therefore if the whole Body was compoſed of Arteries or Veſſels which had the ſame Proportion to their Cavities, as the Arteries have to theirs, the Blood would be to the ſolid part of the Body, as 1.7 to 1, and a body weighing 160 Pound, would have 100 Pound of blood.

*The Proportion of the Blood in the Veins to the Coat of the Veins.*

After the ſame manner I found that the thickneſs of the Coats of the *Vena Cava* of the ſame Calf was 0.0097. The Diameter of this *Vein* was 617, its Square is 0.380689, and $2ab - b^2 = 0.02431596$. If therefore the body was compoſed of Veſſels, whoſe Coats had all the ſame Proportion to their Cavities, that the Coats of the Veins have to theirs, the Blood would be to the ſolid part of the body, as 15,6 to 1, and in a body weighing one hundred and ſixty Pound, there

there would be above one hundred and fifty Pound of blood.

*How the Bulk of the Blood encreases upon a small encrease of the Diameter of the Blood-Vessel.*

It is to be obſerv'd, that theſe Proportions of the thickneſs of the Coats of the *Veſſels* to their Cavities were taken when the *Veſſels* were empty, and conſequently when the Coats were thickeſt, and the Diameter leaſt, for all the *Veſſels*, eſpecially the Arteries, ſhrink and contract when they are empty. Let us ſuppoſe the Diameter of the *Cavity* of the Artery which was 0.407, to be increaſed 0.1. the Square of this *Cavity* would be 0.257049, and conſequently the blood would be to the ſolid part of the body, as 2.7 to 1. If the Diameter were increaſed 0.2 the blood would be to the *Veſſels*, as 3.9 to 1. If 0.3, it would be as 5.3 to 1. From theſe Proportions one may judge more exactly to what

Degree the blood is heated or rarified in inflammatory Feavers, by the Largeneſs of the Pulſe: As alſo how ſmall a Quantity of blood muſt be thrown out at the Heart every Syſtole in languid Feavers when the Pulſe is ſmall.

*How the Arteries may be dilated in Aneuriſms.*

It is ſurprizing to ſee how little the encreaſe of the Diameter of the *Cavity* of the Artery diminiſhes the thickneſs of its Coats; for if we add to the Square 0.257049, the annular Space which we found to be 0.093432, then 0.350481 is the Square of the Diameter of the whole Artery, that is both of its *Coats* and *Cavity*. The Square Root of this Number is 0.592, from which if we ſubtract the Diameter of the *Cavity*, there remains 0.085, the half of which 0.0425 is the thickneſs of the *Coat* of the Artery. Thus I find that the Diameter

meter of the *Aorta* may be encreaſed eight times its firſt bigneſs before its *Coats* become ſo thin as the *Coats* of the *Cava*. This ſhews how prodigiouſly Aneuriſms may dilate the Arteries; and how, when a large Trunk of an Artery in the Arm, Leg or Thigh is tied, the ſmall Arteries (which all communicate with one another) may dilate to carry on the Circulation of the Blood.

*Of the Quantity of the blood in the Fibre of the Muſcles.*

The next ſort of *Veſſels* I come to conſider is the Fibres of the Muſcles, which tho' they may be more bulky, yet they cannot be more numerous than the Arteries; for every Fibre muſt have at leaſt one Artery, and it is probable it has ſeveral. They without doubt have conſiderable *Cavities*, being they ſwell, are blown up, and thereby conſiderably ſhortned when

the Muſcles act. And their ſides can be but thin, or elſe they could not be diſtended by ſo ſmall a Force. Beſides the Blood appears as plainly thro' them as it does thro' an Artery of an equal bigneſs, and therefore we cannot judge their ſides to be thicker than the Coat of an Artery of an equal bigneſs. The Proportion of the thickneſs of their ſides to their Cavities is not to be taken after the Manner we have done thoſe of the Veins and Arteries, but that we might make ſome Eſtimate of it, I made the following Experiment.

I took a piece of the Inteſtine of a Dog, with part of the Meſentery and *Pancreas Aſellii*, and having carefully emptied it of all its Contents, I weighed it exactly with all the Blood in the Veſſels, its Weight was one Ounce and a half,

one

one Drachm and eighteen Grains; then I injected warm Water into the Artery, and having sufficiently washed out all the Blood, I blew it up, and hung it up to dry in the Shade; after it had dried about a Week, I weighed it again, and its Weight was two Drachms, two Scruples, and eleven Grains: By which it appears, that it had lost six hundred and thirty seven Grains, and that there remained only one hundred and sixty one Grains. Now this Loss could be only of the Fluids, which being diluted with the warm Water, were the more easily evaporated, and therefore if the Blood in every part of the body bore the same Proportion to the solid Part, that it does to the solid Part of the Intestines, their Proportions would be 3.9 to 1, and a body weighing one hundred and six-

ty Pound would contain one hundred and twenty ſeven Pound of *Blood*, ſo that even the Fibres of the Muſcles are leſs ſolid than the Arteries. But the Fibres which perform the Periſtaltick Motion of the Inteſtines, are not ſo ſpongy as the Fibres of the Muſcles, for we find them firmer and harder; beſides, if we conſider that the Periſtaltick Motion is performed by a very ſmall Contraction of the Fibres, for which a very ſmall Inflation will ſuffice; but the Contraction of the Fibres of the Muſcles being great, they muſt be conſiderably inflated, and conſequently more ſpongy, and capable of receiving a larger quantity of *Blood*, than the Fibres of the Inteſtines; and therefore it is evident, that in the Muſcles which make up far the greateſt part of the Body, the Proportion of the *Blood*

to

to the ſolid Fibres muſt be above 3.9 to 1, or almoſt as 4 to 1.

*Of the Quantity of Fluids in the Nerves.*

To know what Proportion the Fluids of the Nerves bear to the ſolid Part of the Nerves. I dried a piece of the *Medulla Spinalis* without any Art or Preparation, excepting the ſlitting of it, and I found that it loſt near ¾ths of its Weight, ſo that it appears, that even the Nerves are not more ſolid than the other Parts. And as to the Lymphatick *Veſſels*, I believe every one will eaſily agree, that the Fluids in them bear a much greater Proportion to their Coats, than what has yet been found.

*Of the Quantity of Fluids in the Bones.*

The Bones of all the Parts in the Body ſeem to bid the faireſt for Solidity, and yet even their Fibres are not without their circulating Juices, what elſe is the *Callus* which unites and cements the Extremities

of broken *Bones?* In it there are no Fibres, nor Parts to be distinguished, but it appears like an uniform inspissated Juice. At whatever Time or Age the Misfortune of a broken *Bone* happens, this Juice is always at hand, which shews, that it is always circulating, tho' slowly: If it stagnated, it would harden, as it does when it is extravasated, and forms a *Callus*; and consequently all the Passages being obstructed, no broken *Bone* could unite. This Juice is like to the viscous Sap of Trees; for without doubt a Fluid may move as easily thro' the Fibres of the *Bones*, as thro' the Fibres of an Oak. The Excrescencies of the very Substance of the *Bones*, their Nodes, Swellings, and softening like Wax, of which there are several Instances to be found in Authors, even of Persons

ſons grown in Years, do ſufficiently evince a fluid circulating thro' their Fibres. No doubt but that the older we grow, the narrower are the Channels of the Fibres, the viſcid Fluid hardening towards their Sides, and after Death intirely obſtructing them, ſo that the whole Fibre appears ſolid; but ſtill it is really no part of the Fibre, no more than the Cruſt with which ſome Waters line the Pipes thro' which they run, is part of the wooden or leaden Pipe, or the Glew in which a Sponge has been ſoaked, can be ſaid to be part of the Sponge: And as theſe may be taken out, without taking away any of the Subſtance in which they are contained, ſo likewiſe may this Fluid in the *Bones*. What elſe is the Jelly made of Harts-horn, but a Fluid extracted by boiling Water, the

the Fibres and Subſtance of the Horn ſtill remaining undiſſolved? Is not the Jelly extorted by *Papin*'s Digeſter out of dry and ſolid *Bones* the ſame Fluid? That I might know what Proportion it bears to the Fibres of the *Bones*, I cauſed the *Bone* in the Knuckle of Beef, being firſt boiled, and the Marrow taken out, to be put into the Digeſter. Before it was put in, it weighed 22 Ounces 6½ Drachms, when it was taken out and dried, it weighed 11 Ounces 1½ Drachm, ſo that it loſt above half its Weight, and yet the Texture of the ſmalleſt Fibre in the moſt ſpongy Part of the *Bone* was not broken, and the middle or more ſolid Part appeared to be made of Parallel *Laminæ*, of which four or five would hardly exceed the thickneſs of a Sheet of Paper. And I

doubt

doubt not but that if the Experiment had been made upon younger *Bones*, but that the Proportion of the Fluids to the ſolid Part would have been found to be much greater. Now if the *Bones* contain ſuch a quantity of Fluid, what do the *Tendons*, *Membranes*, *Ligaments* and *Cartilages*, which are much ſofter Subſtances, and which upon boiling likewiſe yield a Jelly? And is not Glew which is extracted out of the Skins of Animals ſuch a ſort of Fluid? So that it is highly probable, that there is not a Fibre in the whole Body, in which ſome Fluid or other does not circulate, but which hardening after Death, and perhaps ſome part of it before, no Elixation whatſoever can extract.

Thus have I conſider'd the ſeveral ſorts of Subſtances in the Body, and ſhewn what Proportion the Fluids

*The Coats of the Veſſels compoſed of other Veſſels.*

Fluids in each of them bear at leaſt to their ſolid Parts, I ſay at leaſt, for no Preparation nor Art can extract a Fluid ſo viſcid, and ſo apt to harden, as the *Blood* is, out of the innumerable Meanders of ſuch infinitely ſmall *Veſſels*. I have alſo ſuppoſed the Coats of the *Veins* and *Arteries* to be perfectly Solid, that is, without Fluids, whereas it is evident to the naked Eye, and agreed on by all *Anatomiſts*, that they are compoſed of *Myriads* of *Veins* and *Arteries*. What an innumerable company does an Inflammation of the Eye ſhew upon the *Tunica Conjunctiva*, and are there not many more to be diſcovered by *Microſcopes*, and the finer the Glaſſes are which we uſe, ſtill the more *Veſſels* we diſcover, ſo that if we can ſee no more, it is only becauſe our Glaſſes are not better. Whoſoever

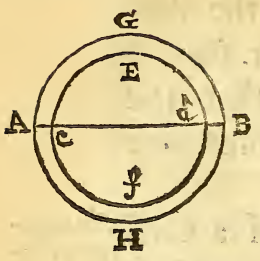
ſoever is acquainted with the Preparations of the curious Dr. *Ruyſck* would be apt to believe that the whole Body, and all its Fibres were nothing but *Blood-Veſſels.*

*The quantity of Fluids in the Coats of the Arteries determined by an Experiment.*

A piece of the *Aorta* of a Calf weighed 240 Grains, when dried, it weighed 80 Grains; ſo that from this Experiment it appears, that the *Blood* in the Coats of the Arteries is to the Coats as 1.7 to 1, which is the ſame Proportion the *Blood* in the great Arteries bears to their Coats, and yet we cannot ſuppoſe that any more than the thin part of the *Blood* was exhaled.

*A general Method to determine the Quantity of Fluids in the Coats of the Veſſels.*

Now therefore, ſuppoſing that the *Veſſels* are made up of others, full of Fluids, and that there is the ſame Proportion of the Fluids to the ſolid Parts in each of them, the Quantity of *Blood* in the Body may




may be thus determined. Let the Annular Space *G A B H, E c f d*, be to the whole Circle *A G B H*, as 1 to *a*; then in a Body compoſed of ſuch Veſſels filled with Fluids, the Fluids will be to the Solids (if the Annular Space is ſolid) as $a - 1$ to 1. But if this Annular Space is likewiſe compoſed of the ſame ſort of Veſſels, then in the whole Body the Fluids will be to the Solids as $a^2 - 1$ to 1: and again, if theſe leſſer Veſſels are compoſed of others ſtill leſs than themſelves, then the Fluids will be to the Solids, as $a^3 - 1$ to 1: and if there ſhould be four ſuch Orders of Veſſels, the Fluids will be to the Solids, as $a^4 - 1$ to 1: if five, as $a^5 - 1$ to 1: if ſix, as $a^6 - 1$ to 1: ſo that the Proportion of the Fluids

to

to the Solids may be increaſed in *Infinitum*. In the Arteries *a* is equal to 2.7, in the *Veins* it is equal to 16.6, and according to the ſeveral Series of *Veſſels*, the *Blood* will be to the ſolid Part of the *Body* in theſe Proportions.

| | | | |
|---|---|---|---|
| 1,7 | | 15,6 | |
| 6,2 | | 274,5 | |
| 18,6 | | 4573 | |
| 52,1 | to 1 | 75932 | to 1 |
| 142,4 | | 1250492 | |
| 286,4 | | 20758082 | |

If the *Body* is compoſed of *Veſſels*, whoſe Coats are made of other *Veſſels*, and theſe again of others, as has been ſaid; then the *Bodies* of the *Animalcula in ſemine*, or the *Prima Stamina vitæ* may be increaſed to any bulk, and the Coats of the *Veſſels* ſo far as we can

*That all the Solids in an animal Body at full growth may be no more than what was in the* Animalcula in ſemine.

can diſcern, grow thicker and thicker, without the Addition of any Subſtance to the *Veſſels*, only by increaſing the Quantity of Fluid, with which they are filled. For as the large *Veſſels* ſwell, ſo likewiſe muſt the ſmall ones, of which their Coats are compoſed down to the very laſt, and the ſwelling of the ſeveral Orders of *Veſſels* muſt neceſſarily increaſe the thickneſs of the Coat of that *Veſſel* which they compoſe; ſo that by increaſing the Number of the Orders of the *Veſſels*, the Coats of the firſt Order of *Veſſels* may be increaſed to any Degree, and yet the Diameter of the *Veſſels* which compoſe theſe Coats, not greater than a given Line.

That the Coats of the great *Veſſels* are compoſed of ſmaller *Veſſels*, is Matter of Fact, and we know nothing to the contrary, but that

that these small Vessels may be composed of others still smaller than themselves. We know not how many *Laminæ* or *Folds* there are in any Membrane of the Body. That excellent Anatomist Mr. *Cowper* informs us, that every Membrane is Vesicular, and may be blown into innumerable Cells. That transparent Membrane the *Cornea* of the Eye consists of as many parallel *Laminæ*, as the nicest Hand of the most expert Anatomist can raise. That delicate thin Membrane which involves the *Brain*, divides its self into two *Laminæ*. And it is very probable, that the *Hydatides*, of which several are found within one another, are nothing but the Coats of the Lymphatick Vessels, distended and separated by the Lympha, and yet it is hard to conceive any thing thinner than the Coat of a

Lympheduct, which is not visible but when it is distended with Lympha. If we know not the Number of *Laminæ* which compose the Membranes, how can we reckon the Number of Fibres, of which the *Laminæ* consist? Or how should we discover the Number of Fibres, of which each Fibre is made up? *Leeuwenhoeck* tells us, That the Fibre of a Muscle which was nine times smaller than a hair of his Beard was made up of a hundred smaller Fibres, and yet each of these must have had Nerves, Veins and Arteries, and perhaps each of them made up of a hundred more: For of how many Series of Vessels any one Vessel is made up of, is what no Microscope can discover; because only one Order can lie at a time in the *Focus* of the Glass, and if more

more could, their ſeveral Refractions would confound the Sight.

If all the ſolid part of the Body was contained in the *Animalcule*, then *Accretion* and *Nutrition* are nothing but the Repletion and Diſtention of the Veſſels, and it is eaſie to conceive how *Helmont*'s Tree grew from five pound Weight in five Years time, to one hundred and ſixty nine Pound, only by the Addition of Water: Nor does this at all contradict the Ingenious Doctor *Woodward*'s Experiments concerning Vegetation, but his Experiments are rather a Confirmation of this Doctrine. For the fewer Terreſtrial Particles are contained in the Water by which any Plant is nouriſhed, the quicker the Water paſſes off thro' the Pores or Excretory Ducts of the Plant, and con-

*Nutrition nothing but Diſtention.*

ſequently the leſs the Veſſels are diſtended; but if the Water is impregnated with a large quantity of terreſtrial Matter, it cannot paſs off quickly, but being retained in the Plant, the veſſels muſt be diſtended, and conſequently the Bulk of the Plant increaſed. That the fewer terreſtrial Particles the Water contains, the quicker it paſſes off, is evident from Experiments: for two Plants of Mint, near of the ſame Weight, ſet at the ſame time, the one in Rain-Water and the other in Thames-Water (which is more copiouſly ſtored with terreſtrial Matter) this did thrive to almoſt double the bulk of that, and with a leſs Expence of Water; yet the Experiments do ſufficiently evince, that Plants require a proper Nouriſhment, as well as Animals, without

without which they can never kindly thrive. For Life is continued, and all its Functions performed by the ſtraining off of ſeveral ſorts of Juices from the common Fluid, which in Animals is called Blood: But if this common Fluid cannot afford theſe Juices, or is not fit to be turned into them, then that Body whether vegetable or animal, muſt turn ſickly, and at laſt die. Some ſorts of Water are more eaſily tranſmuted into the Juices of ſome Plants than others, for we ſee ſome love a very dry and ſome a very wet Soil, and ſome will grow in Water alone, and therefore it was that *Helmont*'s Willow Tree grew to ſuch a Bulk.

*No equivocal Generation.*

If the moſt proper Food can only diſtend but not increaſe or add to the Subſtance of the ſolid Part of

the Body, how much more reaſonable is it to ſuppoſe, that no Matter, howſoever diſpoſed, can at firſt frame theſe ſolid Parts, without an Omnipotent Power immediately actuating it.

*The Poſſibility of the Reſurrection of the ſame Body.*

And does not all that has been ſaid demonſtrate not only the Poſſibility but likewiſe the great Probability of that Suppoſition, which the Reverend and Learned Mr. *Clark* uſes to ſhow the Poſſibility of the Reſurrection of the ſame Body; for if all the ſolid Parts are no more than the Original *Stamina*, and all Nouriſhment only a Fluid in a perpetual Flux, then no Part of an animal Body can become Part of another animal Body; but the Body is always the ſame, from the firſt Moment of Life to the laſt.

But

But whether the Coats of the Veſſels are compoſed of others, or not, the Experiments I have brought do clearly demonſtrate that the Fluids in the Body are to the Solids at leaſt as 3.9 to 1, and therefore in a Body weighing one hundred ſixty pound, there muſt needs be one hundred twenty ſeven pound of Blood. From which Quantity that I may put the matter out of all manner of Diſpute, I ſhall deduct the Weight both of the Fat and Bones, tho' I think that ſome Arguments might be alledged to prove that even the Fat circulates, and I have already ſhown that there is a Fluid in the Bones.

*The Weigh of the Fat and Bones deducted from the Quantity of Blood.*

In a Body weighing one hundred ſixty pound, I ſhall ſuppoſe that the Fat is an Inch deep all round the Body, and in ſuch a mean Weight, I believe this will be ſuf-

ficient to anſwer for all the Fat every where elſe. Dr. *Wainewright* reckons the Surface of the Body meaſures fifteen ſquare Feet, and therefore the Fat muſt be one hundred eighty cubick Inches. Now a cubick Inch of Fat weighs about half an ounce or ſomething more, and therefore the whole Fat of the Body of a Man weighing one hundred ſixty pound is ninety ounces, or five pound ten ounces; but I ſhall ſuppoſe it to be ſeven, and that the Bones weigh twenty pound, and there remains one hundred pound for the Quantity of Blood in a Man weighing one hundred ſixty Pound.

*Concerning the Velocity of the Blood.*

Having in the firſt Treatiſe ſpoke of the Nature and Quality of the Blood, and in this of its Quantity; it will not be improper in this Place to ſay ſomething

thing concorning its abſolute Velocity.

All who have wrote of the Velocity of the Blood ſince the Diſcovery of its Circulation by the immortal Dr. *Harvey*, have contented themſelves only to calculate the Quantity which paſſes through the Heart in ſome determined Time: But none has as yet given us the abſolute Velocity with which it is thrown out of the Heart, runs throw the *Aorta*, or any of its Branches. Many have indeed ſpoke of the rapid Motion of the Blood, and that it muſt be much greater near the Heart than in the Extremities; but how much greater it is in that than in theſe, or whether it moves through the *Aorta* at the rate of 5, 10, 100, or 1000 Feet in a Minute, is what has never as yet been determined; tho' next to the

Circu-

Circulation of the Blood its ſelf, it ſeems to be a thing of the greateſt Moment for explaining of the animal Oeconomy. After the Motion of the Blood was once determined, methinks it was but natural to have enquired in the next Place with what Degree of Velocity it mov'd.

The Velocity of the Blood in the *Aorta* may be thus determined.

*The Velocity of the Blood in the* Aorta.

The Velocity with which a Fluid flows out of any Orifice uniformly and always running in the ſame Quantity, is equal to the Velocity of a Body which deſcribes a Space of the ſame length with that of a Cylinder whoſe Baſe is equal to the Orifice, and whoſe Magnitude is equal to the Quantity of the Fluid that runs out in the ſame time, as 'tis evidently ſhown in the *Lectiones Phyſicæ Jo. Keil, pag.* 114. Now ſuppoſe

ſuppoſe the Heart contracts eighty times in a Minute, and that each Contraction throws into the *Aorta* one Ounce of Blood. An Ounce of Blood is equal in bulk to 1, 659 inch, and conſequently 80 Ounces are 132, 72 inches. The Diameter of the *Aorta* in a middle ſiz'd Man, I have found to be 0, 73 Parts of an Inch, and therefore its Orifice is 0, 4187, by which divide 132, 72, the Quotient 316 inches or 26 feet gives the length of the Cylinder, or the ſpace through which the Blood will go in a Minute, ſuppoſing it were conſtantly going out of the Heart with the ſame Velocity: But becauſe of the *Diaſtole* of the Heart, which is at leaſt half the time of a Pulſation, there goes out 80 Ounces in half a Minute, and conſequently the Velocity of the Blood is at leaſt twice

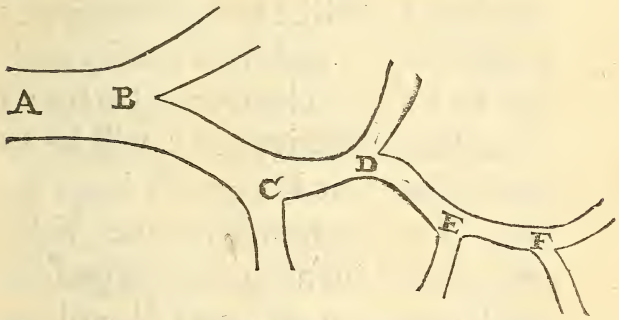
as

as great, or ſuch as will make it to move at the rate of 52 Feet in a Minute: I have ſuppoſed that the Quantity of Blood that the Heart throws out every *Syſtole* is only one Ounce; becauſe that (being allowed of by all) gives the leaſt Velocity, and we are ſure it is at leaſt ſo much; but if every *Syſtole* throws out two Ounces, as many do ſuppoſe, then the Velocity is double to what it has been here determined.

If the ſum of the Sections of the Branches of the Arteries were always equal to the Section of their Trunks, and if the Circuits in which the Blood moves were every where equal, the Velocity of the Blood would be every where the ſame it has been determined to be in the *Aorta*. But we find that the ſum of the Sections of the Branches do

every

every where exceed the Section of their Trunks, and therefore the Velocity of the Blood muſt decreaſe as the Number of Branches increaſe. Now let us ſuppoſe that the ſum of the Sections of the Branches, bears every where the ſame Proportion to their Trunks, and




ſuppoſe A the Trunk of an Artery, and that at B it divides into two Branches, and the Branch B likewiſe into two at C, and that again inro two at D, and ſo on: call A the Section of the Artery, the ſum of the Sections of the Branches at B call B, and thoſe at C

let them be named C, and thoſe at D, E and F call alſo D, E and F. Let the Section of the Canal or Branch B C, be to the Section of the two Branches at C, as A is to B. Likewiſe the Section of the Canal C D to the Section of the two Branches at D, as A to B, *&c.* Then the Velocity at A, will be to the Velocity at B, as B is to A, and the Velocity at B, will be to the Velocity at C as B is to A, and the Velocity at C, will be to the Velocity at D, as B is to A, *&c.* Let A repreſent the Velocity at A, then $\frac{A^2}{B}$ will repreſent the Velocity at B, and $\frac{A^3}{B^2}$ will be the Velocity at C; the Velocity at D will be $\frac{A^4}{B^3}$, that at E will be $\frac{A^5}{B^4}$, that at F will be $\frac{A^6}{B^5}$: and if the Artery be divided into a hundred ſuch Branches before it come to the ſmalleſt, the Velocity at the laſt of them will be $\frac{A^{101}}{B^{100}}$, if into a thou-

ſand

ſand, the Velocity at the laſt of theſe will be $\frac{A^{1001}}{B^{1000}} = A \times \frac{A^{1000}}{B^{1000}}$ = to the thouſandth Power of $\frac{A}{B}$ multiplied by A: The Velocity therefore at A, is to the Velocity after a thouſand branchings, as A is to $A \times \frac{A^{1000}}{B^{1000}}$, that as is 1 to $\frac{A^{1000}}{B^{1000}}$ or as 1 is to the thouſandth Power of $\frac{A}{B}$.

Thus if the *ratio* of A to B was known, the Velocity of the Blood at the ſeveral branchings of the Arteries might eaſily be determined; but this is only to be found by meaſuring of the Arteries, and by the Meaſures which I have formerly taken I find the *ratio* in different Places to be very different. I wiſh thoſe who have more Leiſure and Opportunity, would meaſure the Circumference of an Artery injected with Wax, both above and below each Diviſion, by which means we might come to a greater

Certainty in this Matter. The moſt general Proportions of the Trunks to their Branches that I have found are as 41616 to 43506 and as 41616 to 52126: Now if we take the firſt of theſe Proportions, $\frac{A}{B}$ is 0.9565, whoſe Logarithm is 9.9806850 : This Logarithm multiplied by 30, gives the Logarithm of the 30th Power of 0.9565 : Now the Logarithm 9.9806850 multiplied by 30 is the Logarithm 9, 4205500, to which the Number anſwering in the Tables is 0.26336. That is the Velocity at A in any Artery, is to the Velocity at the 30th branching as 1 to 0.26336, or as 100000 is to 26336 which is almoſt as 4 to 1 : The Logarithm of 0.9565 multiplied by 100 gives for the Logarithm of the Velocity at the 100th branching 8.0685000, the

the Number anſwering to it in the Tables is 0,011708: Hence the Velocity of the Blood in the *Aorta* is to the Velocity in the hundredth Diviſion as 1 to 011708, or as 1000 000 to 11708, that is, it will be almoſt an hundred times greater. But if we ſuppoſe that the Artery divides a hundred times before it comes to the ſmalleſt Capillary or evaneſcent Artery. The Logarithm of the thouſanth Power of 0,9565 is 80.6850000 whoſe Number is 0,0000 000 000 000 000 000 484, and conſequently the Velocity in the *Aorta* will be to the Velocity in its laſt branches in a greater Proportion than 10000 000 000 000 000 000 to 1.

If the Proportion between the Trunk of an Artery and its Branches be taken to be as 41616 to 52126,

then $\frac{A}{B}$ is 0, 7983; and at the hundredth Diviſion the Velocity of the Blood in the Trunk will be to the Velocity in the Branches as 10 000 000000 000 to 16466. At the 200th diviſion as above 10 000 000 000 000 000 000 to 1 : At the 400th it will be as 10000 0000 00000 00000 00000 00000 00000 00000 to 1. Thus having ſhewn how the Velocity of the Blood may be determined at each branching of the Artery, our next enquiry muſt be to find out how many times an Artery may divide before it becomes the ſmalleſt Capillary, which may be thus done.

Suppoſe the *ratio* of the Trunk to the Branches to be as r : s. and call the Trunk c, then r : s : : c : $\frac{sc}{r}$ which is therefore the ſum of the two firſt Branches, and each Branch is $\frac{sc}{2r}$ again r : s : : $\frac{sc}{2r}$ : $\frac{s^2c}{2r^2}$ this is the ſum

ſum of the ſecond branching, of which $\frac{1}{2}$ is the Branch $= \frac{s^2 c}{4r^2}$, and juſt ſo the third Branch will be $= \frac{s^3 c}{8r^3} =$ to the Cube of $\frac{s}{2r}$ multiplied by c.

Now if we call the number of branchings $x$, and $\frac{s}{2r} = d$, the laſt Branch will be $d^x c$. Let us ſuppoſe the ſmalleſt Artery has its Diameter $\frac{1}{100}$ part of a Hair's Breadth, and that the Diameter of a Hair is the $\frac{1}{200}$ part of an Inch, the Section of this Artery will be 0,000 000 00 25, which I ſhall call $= e$. Then we have this Equation $d^x c = e$, which expreſſed by Logarithms is $x \times$ Log. d. + Log. c = Log. e, and $\frac{\text{Log. e} - \text{Log. c}}{\text{Log. d}} = x$.

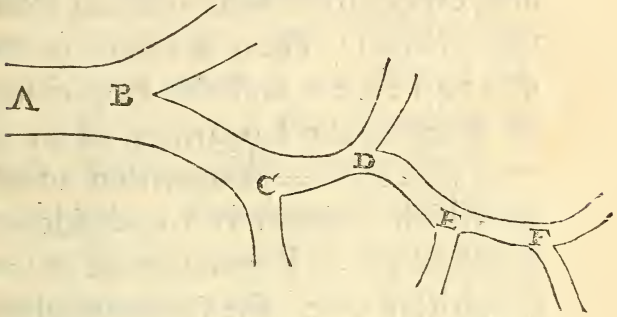
Let us take the Proportion between the Trunk and the Branches to be as 41616 to 43506 :: r : s, then the Logarithm of s divided by 2r is — 0.2817412 = Loga-

rithm of d, it being equal to the Logarithm of s *minus* the Logarithm of 2r: The Logarithm of e is — 8.6020600, and ſuppoſing c equal to the Diameter of the *Aorta* equal to 0,5329 Decimals of an Inch, its Logarithm is---0.2733543, and the Logarithm of e *minus* the Logarithm of c is — 8,3287057, this divided by — 0,2817412 gives in the Quotient ſomething leſs than 30 for the Number of branchings between the *Aorta* and the ſmalleſt Capillary, and conſequently the Velocity of the Blood in the *Aorta* is about four times greater than it is in the laſt Diviſion of the Artery.

But this number of branchings is undoubtedly too few, if we conſider the number of Arteries it produces for the whole Body.

For

For at F the number of Branches are 2, at E 4, at D 8, at C 16, at B 32, and therefore at 30 the




number of Arteries in the whole Body will be the 30th Power of 2 which is 1073 000 000, a number which muſt be prodigiouſly ſhort of the true number, if we conſider that every Fibre of a Muſcle, and every Veſicle of a Fibre is nothing but a Net-work of Blood Veſſels. The *ratio* therefore of the Branches to their Trunks muſt be much greater than 41616 to 43506, and in fact we do frequently find it greater. Let us therefore ſee what the

number of Branchings will be from the other *ratio* of 41616 to 52126, which is almoſt as frequent as the firſt, eſpecially at ſome diſtance from the *Aorta*: Then 41616 is to 52126 : : r : s. and the Logarithm of s *minus* the Logarithm of 2r is — 0.203237 = Logarithm of d, by which number if we divide — 8.3287057 = Logarithm of e — Logarithm of c, the Quotient gives for the number of branchings above 400 and conſequently the greateſt Velocity of the Blood will be to the leaſt in a greater Proportion than 1000 00000 00000 00000 00000 00000 00000 00000 to 1.

Thus we ſee how prodigiouſly the Velocity of the Blood decreaſes as the number of branchings encreaſe; and tho' perhaps we have not taken the exacteſt *ratio* of the Branches

Branches to their Trunks; yet whenever that ſhall be known, the Method we have here uſed, is that whereby the Velocities at the ſeveral branchings may be determined. This much I am aſſured of, the laſt *ratio* of the Branches to their Trunks falls much ſhort of what I have found in ſeveral Places of the Body, and I am apt to think that the *ratio* encreaſes every Diviſion from the great Arteries. Some nice and exact Meaſures of the *Veſſels* taken after the manner I have propoſed would give us a certain Knowledge of this part of the animal Oeconomy.

But till this exact *ratio* is diſcovered, let us ſuppoſe the leaſt Velocity to be as we have calculated it at the hundredth Diviſion only that is 1000000000 times leſs than it is in the *Aorta*; then when

the Blood in the laſt Diviſion of the Artery moves one Foot, that in the *Aorta* moves 1000000000; now the Blood in the *Aorta* moves at the rate of 52 Feet in a Minute, and conſequently it moves 100000000 Feet in 13354 Days, in which time the Blood at the hundreth Diviſion moves only one Foot, or it would be 278 Days in moving of a Quarter of an Inch, if the laſt Branches were ſo long: But if the leaſt Velocity is at the ſeventieth Diviſion, the Blood will move there at the rate of a Foot in about thirteen Days: And at the fiftieth at the rate of a Foot in three Hours.

As between the greateſt and the leaſt Velocity we are to conceive all the intermediate Degrees; ſo we are not to imagine that in every evaneſcent Artery there is the leaſt Velocity, but only in ſuch as have an hundred

dred Diviſions between them and the great Artery, and the Velocity of the Blood in the evaneſcent Arteries is every where proportionable to the number of Diviſions between them and the great Artery; and therefore in all the ſmall Arteries which come immediately from the *Aorta*, and which after a few Diviſions tranſmit their Fluid to the Veins, the Velocity of the Blood is but a little diminiſhed.

From all this it appears that when the whole Maſs of Blood is to be altered, that the Courſe of Phyſick ought to be continued for a long Space of time, being the Blood moves ſlower and ſlower the farther it moves from a great Artery, and conſequently it muſt be a great time before the whole Maſs of Blood can be mixt with the alterative Medicine. And being the

Circulation of the Blood through Glands which receive Arteries immediately from a great Veſſel, is very quick, they may carry off a great Proportion of the Medicine in a very little time, and therefore it is not the taking of great Quantities, but a conſtant taking that can alter the Maſs of Blood; and from hence it follows that when the Blood is to be altered by mineral Waters, which are apt to paſs through the Glands of the Kidneys, that they ought not to be drunk in large Quantities: For if they paſs off, they have not the deſigned Effect; and if they do not, being drunk in a little time, they mix but with a ſmall Quantity of Blood, which muſt diſorder the animal Oeconomy.

*Of*

## *Of Muſcular Motion.*

A Muſcle is a Bundle of thin and parallel Plates of fleſhy Threads or Fibres, encloſed by one common Membrane: All the Fibres of the ſame Plate are parallel to one another, and tied together at extremely little diſtances, by ſhort and tranſverſe Fibres. The fleſhy Fibres are compoſed of other ſmaller Fibres encloſed likewiſe by a common Membrane: Each leſſer Fibre conſiſts of very ſmall *Veſicles* or Bladders into which we ſuppoſe the Nerves, Veins and Arteries to open; for every Muſcle receives Branches of all thoſe *Veſſels*, which muſt be diſtributed to every Fibre. The two Ends of each Muſcle, or the Extremities of the Fibres, are

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in the Limbs of Animals faſtened to two *Bones*, the one moveable, the other fixt, and therefore when the Muſcles contract, they draw the moveable *Bone* according to the Direction of their Fibres. When the Muſcles contract in length, they ſwell in thickneſs, as may be perceived by laying the Hand upon the *Maſſeter* a Muſcle of the lower Jaw, and preſſing the Grinders together: but this Power of contracting or ſwelling is loſt when either the Artery or Nerve of the Muſcle is cut or tied, and therefore we conclude that the Contraction, Swelling, or Motion of the Muſcles is performed by the *Blood* and *Animal Spirits* diſtending the *Veſicles* or Cavities of the Fibres. This Diſtention of the *Veſicles* of the Fibres muſt be either by their being filled with a greater Quantity

of

of *Blood* and animal Spirits than they were before the Contraction, or the *Blood* and Spirits mixing muſt rarifie, and fill up a greater ſpace.

That the *Veſicles* of the Fibres are not diſtended purely by the Quantity of *Blood* and Spirits will appear if we conſider, that were the *Veſicles* diſtended only by the Quantity of Fluids contained in them, Nature (whoſe Operations are always the moſt ſimple) had only uſed one Fluid and not two; for in the Works of Nature we no where find two neceſſary Cauſes where one could have produced the ſame Effect: Now how ſmall ſoever we ſuppoſe the Quantity of Fluid brought by the Nerves to the Muſcles, that alone might have contracted the Fibres (if a Quantity only of a Fluid had been requiſite) by

by diminiſhing the Diameters of the Cavities or *Veſicles* of the Fibres, as will appear by the ſequel of this Diſcourſe. And as it is evident that the reaſon why the Spirits alone do not diſtend the *Veſicles*, is not that there is not a ſufficient Quantity for that purpoſe; ſo it will likewiſe appear that if there had not been a ſufficient Quantity of the nervous Fluid, yet the Quantity of Blood could have given no aſſiſtance in the Diſtention of the *Veſicles*; for if the *Veſicles* contain a greater Quantity of *Blood* when the Muſcles contract, than they do when the Muſcles are relaxed, this Augmentation muſt proceed either from the *Bloods* being ſtop'd in the *Vein*, or it muſt move ſuddenly with a greater *Velocity* thro' the Artery into the Cavities of the Fibres. If the *Blood* is ſtopp'd in the

the *Vein*, it muſt be by the Contraction of its Coats, or by ſome external Preſſure upon them: If by the Contraction of the Fibres which compoſe the Coats of the *Vein*, the ſame difficulty remains to be explained, for whatever is the cauſe of the Contraction of the Fibres of a *Vein*, will likewiſe ſerve to contract the Fibres of a *Muſcle*. If the *Blood* is ſtopp'd in the *Veins* by a preſſure upon their Coats, it muſt be by the ſwelling of the Artery or Muſcular Fibres. If the Artery ſwells and preſſes on the *Vein*, the Circulation of the *Blood* muſt be intirely ſtopp'd; for that Preſſure will conſtantly encreaſe, the *Blood* being ſtill accumulated in the Artery, and therefore it will for ever hinder all Paſſage through the *Vein*: If it be ſaid that the *Blood* moving ſometimes with a greater *Velocity*

through the Artery into the Cells or *Veſicles* of the Fibres, will diſtend them; this greater *Velocity* muſt proceed from the force of the Heart, from which alone the *Blood* derives all its Motion: Now if the Heart acts with a greater force it will encreaſe the *Velocity* of the *Blood* univerſally throughout the whole *Body*, and each Muſcle and its Antagoniſt will be thereby equally contracted, and conſequently neither will contract. And therefore being both the *Blood* and Fluid of the Nerves are neceſſary to the Contraction of the Muſcles, and being the Contraction is not performed by the Quantity of theſe Fluids, it remains only that by their Mixture, they rarifie and diſtend *Veſicles*.

Now for the explaining of this Rarifaction of the *Blood* and Spi-

rits

rits in the *Veſicles* of the muſcular Fibres, let us ſuppoſe a ſmall Globule of Air between the Particles of a Fluid, and that the Particles have a ſtrong attractive force by which they endeavour to come together, they preſſing every way equally on the Globule of the Air, will hinder it from eſcaping any way from between them; but the force by which they endeavour to come together, being prodigiouſly greater than the force of their Gravity, they will by this force produce a very conſiderable Condenſation of the Globule of Air that lies between them, and the force of Elaſticity being proportional always to its Condenſation, the force by which this airy Globule will endeavour to expand its ſelf, will likewiſe be vaſtly great; and conſequently if by any means this *Niſus*

of the Particles of the Fluid to come together ſhould be taken off, the Air between them would expand its ſelf with a very conſiderable force. Now if upon the mixing of another Fluid the Particles of the firſt Fluid ſhould be more ſtrongly attracted to the Particles of this other Fluid, than they were before to one another, then would their *Niſus* to one another ceaſe; and they would give the Globule of Air that is between them, liberty immediately to expand it ſelf; and the whole Fluid would take up a greater ſpace than it did before. But when the Particles of the two Fluids come to be united together, they will again encloſe the Globule of Air that lies between them, and by their mutual Attraction ſoon bring it to its former State of Condenſation.

Now

Now that the *Blood* contains a great number of Globules of Air is evident from the Quantity it yeilds in the Air Pump. And that the Particles of the *Blood* have a ſtrong attractive force is likewiſe plain from what has been ſaid in the Theory of Secretion. By this Attraction of the Particles, the Globules of the *Blood* are formed; and in viewing the Circulation of the *Blood* with a Microſcope, I have ſometimes obſerved, that where the Diameter of the Canal has been leſs than the Diameter of a Globule of *Blood*, that the Globule would be preſſed into a Spheroidical Form, but when it came into a wider part of the Canal again it would immediately reaſſume its former Figure; which I think is probably owing to a ſmaller Globule of Air encloſed within, and expand-

ing its ſelf equally every way, when the ſides of its circumambient Shell of *Blood*, are not longer preſſed by the ſides of the Canal.

Theſe Globules of *Blood* continually circulating through the *Veſicles* of the Fibres (which are probably capable of containing only one Globule at a time) meet with the Animal Spirits, which drop from the Nerves. Now the Minuteneſs of the *Glands* of the Brain, and the Smalneſs of the Fibres of the *Nerves*, plainly ſhow that the *Animal Spirits* are a Fluid, conſiſting of the ſmalleſt Particles of any in the Body; and therefore their attractive Force muſt be the greateſt of all the Particles in the Blood, as is evident from what Sir *I. Newton* has calculated about the Rays of Light; and conſequently the *Animal Spirits* meeting with the *Globules* of the

Blood

Blood in the *Veſicles* of the Fibres, and ſurrounding them, muſt attract the Particles of which they are compoſed, more ſtrongly than they do another; and conſequently their *Niſus* to one another ceaſing, the condenſed Globule of Air will expand its ſelf with a very conſiderable force, whereby each *Veſicle* of the Fibre will be diſtended, and conſequently the Fibre ſhortned, *i. e.* the whole Muſcle will be contracted. But when the Particles of the Globule of *Blood* are mixed with the nervous Fluid, they will both together encloſe the Globule of Air again and compreſs it into as ſmall a ſpace as it was before, and thus the Contraction of the Muſcle muſt immediately ceaſe; unleſs freſh Blood and Spirits ſtill ſucceeding one another continue the Inflation of the *Veſicles*. But when a Muſcle

has been ſtrongly contracted for ſome time, the Quantity of Spirits ſpent, being more than can be ſecerned in the ſame ſpace of time by the Glands which ſupply its Nerves, the Inflation of the *Veſicles* muſt fall, and the Muſcle grow feeble and weak; whereas the Tonick Motion of the Muſcles, being performed by the Spirits protruded only by the Quantity laſt ſecerned in the Glands, will conſtantly continue without any wearineſs.

After this manner I conceive the *Veſicles* to be diſtended without any Ebullition or Effervescence, and their Diſtention to ceaſe without any Precipitation, or flying off of the aerial Globules through the Pores of the Muſcles. For to this Attraction of the Particles of Matter is owing moſt of the *Phænomena*; for explaining of which, Philoſophers have

been forced to have recourſe to active and ſubtile Particles, which contrary to their own Principles they have made to move themſelves every way, and to do what ever they had a mind ſhould be done: But how theſe Particles came by ſo great an Activity was not at all to be accounted for from any of their Principles. Thus in explaining of Muſcular Motion they make the animal Spirits to cut and pierce the Globules of Blood, and with their ſharp Points to run them through and through, that the impriſon'd Elaſtick *Aura* might be ſet at liberty; which notwithſtanding could not be effected, unleſs we ſuppoſe that Holes may be made in Fluid Globules, as in a Board, and that the Fluid Particles ſtand in a Heap, as the Waters of the Red Sea did. And when the Aerial Globule is

got looſe, the Intumeſcence of the *Veſicle* cannot be aſſwaged, but by ſuppoſing the Elaſtick Globules now to have Strength to break through the Muſcles and Skin to come at the external Air, tho' before they had not Power nor Subtilty enough to get through a thin Shell of Blood.

But I come now to ſhow the Mechaniſm of the Fibres, or how excellently and wiſely they are contrived for contraction: It is a known Experiment that a Bladder when it is blown up and diſtended as to its Capacity, but contracted as to its length, will by the force of Contraction, raiſe a Weight to ſome determined height. And if two Bladders joined together and communicating with one another were blown up, the Weight would be raiſed by Inflation twice the

ſpace that one alone would do it; becauſe I ſuppoſe that both Bladders contract equally, and conſequently the Contraction of both together will be double the Contraction of either. Three Bladders thus joined and diſtended will raiſe the Weight to triple the Height, and four to quadruple; ſo that if there were a String of Bladders join'd together, of equal Bulk, and like Figures, the ſpace through which the Weight wou'd riſe, wou'd be proportional to the number of Bladders, or, which is the ſame thing, to the length of the String.

Each Fibre of a Muſcle conſiſting of a Multitude of ſmall *Veſicles*, reſembles a ſtring of Bladders; and therefore the Contraction of the Muſcle, is always proportional to the length of its Fibres. And being

ing the greateſt Contraction of the Fibres is always leſs than $\frac{1}{5}$ of their length (as ſhall hereafter be demonſtrated) there was a neceſſity that the Inſertions of the Muſcles ſhould be near to the Joints, not only to encreaſe the Velocity of the Parts moved; but likewiſe that they might deſcribe greater Arches round the Centers of their Motion: And hence it is that thoſe Parts which deſcribe the greateſt Arches, are moved by the longeſt Muſcles; as the Hand round the Elbow which is bent by the *Biceps* ariſing from the *Scapula*, and the Foot round the Knee which is bent by the Muſcles whoſe Originations are as far diſtant as the *Iſchium*. If theſe Joints had been moved by ſhort Muſcles inſerted at each end into the Extremities of the articulated Bones, the Arm and Leg had moved

ved but a little way, and the Arches the Hand and Foot had deſcribed about theſe Joints, had been to the Arches they deſcribe now, as the length of the ſhort Muſcles had been to the length of the Muſcles they have now. On the contrary, where the Joints have but a ſmall Motion there the Muſcles are ſhort; thus we find that the Fingers are pulled ſideways by the *Interoſſei*, the Thigh is drawn outwards, and obliquely by the *Quadrigemini* and *Obturatores*, which are all ſhort Muſcles, and moſt of the Muſcles of the *Vertebræ* run between one *Vertebra* and the next. From hence it is evident that the Originations and Inſertions of the Muſcles, are every where the beſt that could be contrived.

The Veſicles of which the Fibres conſiſt are extremely ſmall, for tho'

one

one large Bladder may raiſe a Weight as high as ſeveral ſmall ones, yet the Quantity of Elaſtick Fluid uſed in the Inflation together, with the ſwelling of the large Bladder, will be much greater, than when a Weight is raiſed by a ſtring of ſmall ones. For ſuppoſe two Bladders of ſimilar Figures, but the Diameter of the one triple of the Diameter of the other, then will the one require twenty ſeven times the Quantity of Elaſtick Fluid to expand it that the other does, and it will ſwell to twenty ſeven times the ſpace; and yet three of the leſſer Bladders joined together will raiſe the Weight to the ſame Height that the bigger one does, but with nine times leſs Expence of Elaſtick Fluid, and they will take up but one ninth Part of the ſpace. By diminiſhing there-

therefore the Bigneſs of the Veſicles, and encreaſing their Number, the force required to diſtend the Veſicles, and the Diſtention its ſelf may be diminiſhed in any given Proportion, and come at laſt to be inſenſible. Suppoſe a Bladder of a determined Bigneſs can raiſe a Weight a Foot; a hundred Bladders whoſe Diameters are each $\frac{1}{100}$ part of the former being blown up will raiſe the Weight to the ſame Height, but the force of Inflation and the ſwelling of all put together will be ten thouſand times leſs than in the large one.

If a Weight of a determined Bigneſs can be raiſed to a certain Height by one Bladder, or one String of Bladders to which the Weight is tyed; twice that Weight may be raiſed by two ſuch Bladders, or Strings of Bladders, and

triple

triple that Weight by three ſuch Strings. And conſequently the Weight a Muſcle can raiſe, will be always as the Number of its Fibres, that is, as its Thickneſs ſuppoſing the Diſtention of the Veſicles equal. And the abſolute Strength of one Muſcle is to the abſolute Strength of another, as their Bulks.

It is to be obſerved that in determining both the Contraction and Strength of a Muſcle, no regard is to be had to the Tendons; becauſe in them we obſerve no Inflation, and we find nature no where making uſe of a Tendon, but where either there was not room for the Inſertion of ſo many fleſhy Fibres, or where it was neceſſary the Muſcle ſhould draw from ſuch a Point.

I ſhall in the next Place determine the force of the Elaſtick Fluid neceſſary

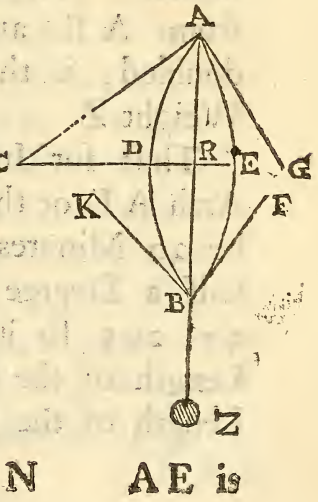
ceſſary to diſtend the Veſicles ſo as to raiſe to a determined Height any given Weight. But before this can be done, the Figure that each Veſicle will be formed into by the force of the Elaſtick Fluid diſtending it, muſt be found out; And therefore let us conceive each Veſicle to conſiſt of an infinite number of Threads, whoſe Ends are faſtened by tranſverſe Ligaments; and from hence it follows that if a diſtended Veſicle were cut with a Plane thro' its Axis, the Curve of the Section will be the ſame with that of a Thread whoſe two Ends are faſtened, and the whole preſſed by an Elaſtick Fluid; and becauſe Elaſtick Fluids endeavour to expand themſelves every way, and all Fluids preſs perpendicularly on each Obſtacle, it is evi-

dent

dent that the Thread muſt be every where equally and perpendicularly preſſed, and therefore its Flexion or Curvature muſt be every where equal and ſimilar, and conſequently the Thread muſt be formed into a circular Arch. Hence it follows that the whole Secretion of the Veſicle conſiſts of two equal and ſimilar Arches, whoſe common Subtenſe is the Axis of the Veſicle. Suppoſe now A E B and A D B to be the two circular Arches, C the Center of the Arch A E B, A G and B F Tangents in the Points A and B, Z the reſiſtance to be raiſed. The Angle CAG or CAE is equal to a right Angle = to C A R + A C R, and therefore the Angle A C R = G A R, or E A R = E B R = D B R and therefore the Arch E A or E B is the Meaſure of the Angle E A R,

or

or E B R, and the Space through which the Reſiſtance Z is raiſed is equal to the difference between the Arch AEB and its Chord ARB, or equal to twice the Difference of the Arch A E and its Sine A R, which having the Arch A E or the Angle E A R given in Degrees and Minutes may be eaſily calculated. But to do this the Length of the Radius A C muſt be determined in ſuch Parts, wherof 100000 make up the Arch A E which is done thus. The Degrees of a circular Arch, whoſe Length is equal to the Radius of the Circle is 57° 295 and therefore the Degrees in the Arch




N AE is

A E is to 57° 295 the Length of the Radius expreſſed in Degrees as 100000, the Parts of which the Arch A E conſiſts, to the Radius expreſſed in the ſame Parts, which will therefore be given. And again, as the Tabular Radius is to the Tabular Sine of the Arch A E, ſo is the Radius A C (which is already found) to the Sine A R which will likewiſe be found. This being ſubſtracted from A E and the Remainder doubled, is the Elevation of the Weight Z.

Thus for Inſtance ſuppoſe the Arch A E or the Angle E B R to be 30 Minutes, ſay as 30′, or half a Degree, that is $\frac{1}{2}$ is to 57° 295 ſo it is 100000 the Length of the Arch A E, to the Length of the Radius A C which will

will be found to be 11459000. And again as 100000 is to 872 the Sine of 30′ ſo is 11459000 to A R which is therefore 99906, which ſubſtracted from A E, and the Remainder doubled, gives 186 the Sublevation of the Weight Z in ſuch Parts whereof A E is 100000.

The Tenſion of the Fibre or the Force wherewith it is ſtretch'd by the Reſiſtance Z may be thus determined. The Tenſion of the Fibre, or the Force ſuſtaining the Weight in the Point B, is the ſame as if the Weight Z were ſuſpended by two Threads touching the Arches in the Point B, and in that Caſe the Tenſion of the Thread B F is to the Weight Z as the Sine of the Angle F B R or E B R is to the Sine of the Angle F B H or E B D

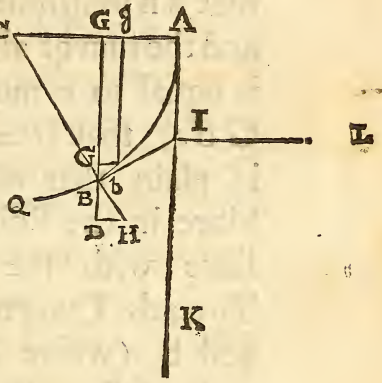
EBD (*a*) and conſequently the Tenſion or Firmneſs of the Thread will be $= \frac{Z \times \text{Sine EBR}}{\text{Sine EBD}}$.

Now call the abſolute force of Expanſion that the Elaſtick Fluid muſt have to raiſe a given Weight to a determined Height n; the Preſſure on any Part of the Thread will be as the Force of Expanſion of the Fluid, and the Portion conjunctly; for if the Portions of the Thread be taken equal, the Preſſures on them will be as the Force of Expanſion, or the Elaſticity, and if the Force of Expanſion be the ſame, the Preſſure is as the Portions on which it preſſes; and therefore univerſally it is as the Force of Expanſion, and the Portion jointly, or as the Product of the two.

(*a*) *By the* 2*d cor. prop.* 33 *of the* Lectiones Phyſicæ Jo. Keil.

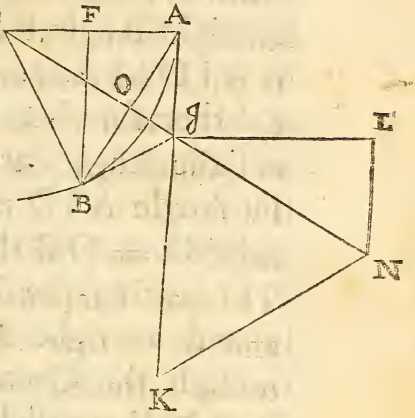
Let

Let A B repreſent the circulare Thread, B b an indefinite ſmall Portion of the ſame, and the Preſſure on B b will be n x B b, which ſuppoſe equal to B H: The Preſſure B H can be reſolved into two Forces, one whereof is as D H acting horizontally, or according to the Direction D H, and the other at B D acting vertically, or according to the vertical Direction B D, and becauſe of the equiangular Triangles G B b and B D H. B G: D H :: B b : B H :: B b : n x B b (:: 1 : n) :: G b : B D, therefore D H = n B G, and B D = n G b, and therefore the ſum of all the



the horizontal Forces will be equal to n multiplied by all the B G's, that is n multiplied by B F = n × B F, and the ſum of all the vertical Forces is equal to n multiplied by all the G b's, that is = n A F. Now it is plain that the Tenſion of the Fibre in the Points A and B is the ſame with the Tenſion of two Threads Tangents in the Points A and B (where they are ſuppoſed to be faſtened) that are drawn at their Point of Concourſe I by all the horizontal Forces according to the Direction I L, and by all the vertical Forces according to the Direction I K: and therefore to determine the Tenſion of the Fibre, the Tenſion muſt be determined of the Threads that are pulled at the Point I by a Force n F B according to the Direction I L, and by a Force n F A

n F A according to the Direction I K. Take I L = n F B and L N perpendicular to it = n F A, and the two Forces I L and L N will be equipollent to a third Force as I N acting according to the Direction I N, and therefore the Threads will be ſtretch'd to the ſame Degree by the Force I N that they would be by the two Forces I L and L N, and becauſe I L (n B F) : L N (n F A) : : B F : F A, and the Angles at L and F equal (by the 6th of the 6th) the Triangles B F A and I L N will be equiangular, and the Side I N will




be

be equal to n B A, and the Angle F A B = L N I = (by 29. 1) A I O, add the Angle I A O to both, and the right Angle F A I will be equal to A I O + I A O = (32. 1) A O C; and therefore becauſe A I = I B, and the Angles at A and B equal, the Angle A I O muſt be = B I O and A O = O B the Line therefore N O cutting the Line A B equally and at right Angles muſt paſs through the Center. Through N draw N K parallel to B I, meeting with A I produced in the Point K, then the Forces by which the Threads are ſtretched will be as I K and N K, (*a*) the Angle K I N = A I O = F A B = B I O = I N K. The Triangle therefore K I N is an Iſoſceles Triangle, and equiangular

(*a*) Keils Lectiones Phyſicæ *prop.* 33.

to

to the Triangle A B C, and A B : A C : : N I : I K : : n A B : n A C and thererefore I K or K N will be equal to n x A C, that is the Forces by which the Threads are ſtretch'd will be equal to the Radius of the Circle multiplied by n.

Hence the Tenſion of the Fibre in the Points A and B, and ſo in all other of its Parts, is the ſame and equal to the abſolute Force of Elaſticity multiplied into the Radius of the Circle. But the Tenſion of the Fibre was found before to be $\frac{Z \times \text{Sin E B R}}{\text{Sin E B D}}$, therefore if we call the Radius r. $nr = \frac{Z \times \text{Sin E B R}}{\text{Sin E B D}}$ and $n = \frac{Z \times \text{Sin E B R}}{r \times \text{Sin E B D}}$ and r x Sin E B D will have the ſame Proportion to the Sine E B R as Z to n. Hence is is plain that no finite Force of Elaſticity can extend the Fibre A E B D

to a complete Circle, for in that caſe the Sine of the Angle E B D being nothing r x Sin E B D is nothing, and therefore Z will be to n as nothing to ſomething, or as a finite to an infinite.

The greateſt Contraction of the Fibre that can be, muſt always be leſs than 72728 of ſuch Parts whereof the Arch A E, is 100000, for if the Threads were extended into complete Circles, the Contraction would be only $\frac{72728}{100000}$ of A E, which it can never arrive to; therefore the Contraction muſt be always leſs than $\frac{1}{4}$ of the Lengthof the Fibre: It is alſo plain that when the Angle E B R is ſmall, the Force of Elaſticity bears but a ſmall Proportion to the Reſiſtance. For Example when the Angle E B R is but 30′ the Radius or r multiplied into

into the Sine of the Angle EBD the Sine of one Degree, is to the Sine of the Angle EBR the Sine of 30′ as Z to n, that is, r x 1745 : 872 :: Z : n, that is Z : n :: 11459000 x 1745 : 872 :: 19995955000 : 872 :: 22931141 : 1, and conſequently a ſmall Degree of Elaſticity will produce a prodigious Energy in the Muſcles.

*FINIS.*

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